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WEATHER BUREAU

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CORRECTIONS

August, 1929:

Page 329, second column, next to last paragraph, first line, "Table 1" should be "Tables 1 and 2"; fourth line, change "1871" to "1722."

Page 332, Figures 1 and 2, including legends, should be transposed. Figure 1 refers to temperature; Figure 2, to pressure.

MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY

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THE PRACTICAL IMPORTANCE OF CLIMATIC CYCLES IN ENGINEERING

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[Jackson, Mich.]

Science has furnished a vast amount of information regarding the ancient and recent changes of climate. Little, if any, of this knowledge has found its way into the practical arts, such as hydraulic engineering. Works for the control of water are based on records of precipitation, run-off, and water levels and the fluctuations thereof; but thus far no practical use has been made of climatic science for that purpose.

The reasons are twofold: First, the theories of climatic changes from the Paleozoic to the present are still largely controversial; second, the amplitudes of recurring cycles are generally considered too small to be of any importance.

1. SCIENCE OF CLIMATIC CHANGES STILL IN FORMATIVE STATE.

Oswald Heer (1) found that a uniform warm climate existed from the early Carboniferous to the late Cretaceous, based on fossil flora found in Greenland and Spitzbergen. Stigmaria, Calamites, and other Carboniferous flora, as well as Oleander, Magnolia, Ficus from the Cretaceous, once grew in abundance in those polar regions. A division of climate according to latitude is visible, according to Heer, only in the late Cretaceous and the Miocene flora, also found in the polar regions. Heer states: "Nirgends ist die geringste Spur einer Gletscherzeit wahr zu nehmen." This view is opposed by *Melchior Neumayer* (2), who finds many proofs of zonal distribution in the Jurassic and the Cretaceous; also the Carboniferous flora is said to show zonal characteristics. *Doctor Wieland* (*Yale*) states that growth rings have been found in the upper Mid-Devonian Callixylon, as well as in a Carboniferous Cordaites as far south as Texas, which would indicate the existence of seasons long before the Miocene (3). The strongest argument against Heer's uniform climate is the occurrence of glaciation in the Carboniferous. On the other hand, Professor Hobbs holds that Heer's major thesis is still correct.

Similar opposite views prevail concerning recent climatic fluctuations. *Brückner* was severely criticized by the meteorologist *Schreiber* (4) while, on the other hand, *C. E. P. Brooks* states that Brückner's views were immediately accepted (5). *Henry* finds (6), using Brückner's methods on data of the United States since 1890, that the former's results are only partly verified.

The same differences are also found in recent opinion on the relation between the solar cycle and climate. *Huntington* (7) and *Douglass* (8) find relations well established, while *Charles G. Abbott* (3) and *H. Norris Russell* (10) do not. Regarding methods of analysis, divergent opinions also exist. *Bigelow's* (9) and *Clough's* (11) views are not shared by *G. T. Walker*, who apparently does not accept (12) variable cycles, and considers harmonic analysis applicable on weather data, although the necessary mathematical conditions are in that application not satisfied, different results from different parts of the same record are obtained therewith, and extensions do not agree with subsequent observations (13). Instead of a small number of variable cycles, far enough apart to be distinctly separable, *C. E. P. Brooks* prefers to discuss 18 harmonic elements in the Nile floods (14) and *Brunt* 44 harmonic elements in rainfall (15).

Hence, finding that the science of climatic changes is still in formative condition, practical engineering has thus far abstained from applying controversial theories and methods.

2. AMPLITUDES OF CLIMATIC CYCLES ARE SMALL AS COMPARED WITH LOCAL AND MOMENTARY CHANGES.

If cycle studies had produced results in meteorology, their use would probably have penetrated into the engineering field, but thus far they have been of no aid. It has tacitly been assumed that the same results would also be obtained in hydraulic engineering. According to *C. F. Marvin:* The primary obligation of the Weather Bureau is to forecast the weather, and the principle of cycles might be used in this work if the cyclical recurrences are real and the effects important. Real cycles of very small amplitudes would have very little forecasting value (3).

The Brückner cycle of temperature and pressure, as well as the 11-year cycle, have amplitudes altogether too small to be of any significance for forecasting weather. The variation in temperature is on the order of 1° C. or less. On the other hand, a 15° C. difference in the temperature of the same day is a common occurrence (16). The secular variation in pressure is not more than a few millimeters, and the daily changes during storms may be fifteen times as much.

For elements which are measured by accumulation, such as rainfall, the secular amplitudes are larger, although here also the many fortuitous daily changes surpass in amplitude the secular variations of yearly rainfall. For agriculture a severe passing drought, hailstorm, or cloud-burst is of more immediate local concern than a slight change in total rainfall over many years. While the amplitudes of long rainfall cycles are greater than those of either temperature or pressure, it has been impossible to make practical use thereof in weather fore-

casting, because the erratic and fortuitous changes in rainfall are yet many times greater. Repeated investigations have established many possible sources of errors in rain-gage readings. The influence of gage size, exposure, elevation above ground, and wind velocity is well known. The erratic distribution of rainstorms, such as occurred at Cambridge, Ohio, on July 16, 1914, is amply recorded in the annals of the United States Weather Bureau and was recently investigated by Professor *Kassatrine*, of Moscow (**17**). Study of long cycles in rainfall is hampered by the scarcity of reliable long records, as illustrated by *Desmond Fitzgerald* in the Cochituate (**18**) records of the Boston water supply, and by *R. Siedek* in discussing the old "Brander" rain gage of the Austrian hydrographic service (**19**).

Summarizing, it may be said that because cycles in temperature, pressure, and rainfall are largely obscured and surpassed in amplitude by the local and momentary changes, they are of no practical use in weather service.

3. BASIC DIFFERENCE BETWEEN HYDROGRAPHIC AND METEOROLOGICAL DATA.

This conclusion of practical meteorology has been transferred sine qua non to engineering, although the conditions are modified to such extent in hydrographic data that the situation is completely reversed. Here secular amplitudes occasionally surpass the amplitudes of local and momentary changes, and, far from being obscured by the latter, are often visible by mere inspection of the record. On account of this more favorable proportion between the secular and the fortuitous momentary amplitudes the chances for a successful elimination of controversy are more favorable in the application of climatic sequences to hydraulic engineering than to weather service. Although the recent fluctuations in climate are small, it is not necessary that these changes should be large in order to become of great practical importance in hydraulic engineering.

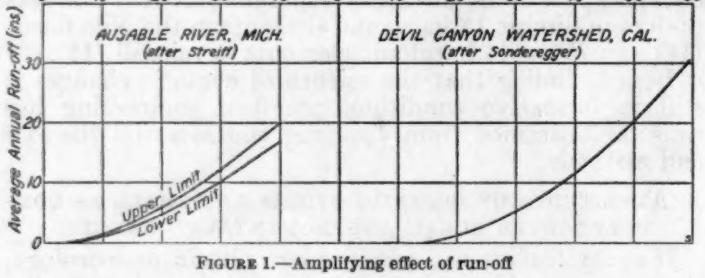

FIGURE 1.—Amplifying effect of run-off

Weather service deals largely with *momentary* values and changes. The task of hydraulic engineering is the control and conservation of water; hence it deals largely with *cumulative* values. Precipitation is collected on large drainage basins and partially runs off. The run-off is again accumulated in lakes and storage basins. The storage quantities and water elevations represent a repeated accumulation, and by this cumulative process small secular differences, unimportant for weather service but sustained over long periods, become great and important effects.

The difference in evaporation from and flow into a lake basin may be delicately small, but the unlimited time factor may nevertheless cause cumulative effects of enormous magnitude. The Great Salt Lake fell 14 feet between 1875 and 1905, or in 30 years, while the climate was merely somewhat drier than usual, and the daily weather changes with the usual hail, rain, and thunder storms probably were not noticeably different than at present with a rising lake level. At the same rate a fall of several hundred feet might, in a sufficiently deep lake, well take place in 500 years; post-glacial lacustrine changes might well occur within the limits of small secular changes of no account in weather service, but sustained through thousands of years.

The post-glacial changes nevertheless were very great. The Great Salt Lake shrunk from 19,750 to 1,750 square miles since the retreat of the ice. The diluvial Lakes Agassiz and Iroquois disintegrated into the present much smaller Lakes Winnipeg and Erie (**20**). *Nachtigal* investigated the enormous extent of the diluvial Lake Tchad in Africa (**21**), while *von Richthofen* has carefully collected evidence of the much greater diluvial areas of Lakes Pangong, Chamoriri, Lob-nor, and many others in Turkestan and Tibet (**22**). According to *Mucshketov*, the Caspian Sea had more than twice its present size, and still has ancient beaches 180 feet above its present level (**23**); a connection existed through the Manytch Valley with the Black Sea and also with Sea of Aral, then more than three times its present size.

The streams which feed such lake basins are also the cumulative result of rainfall on a large drainage area. The erratic nature of rain-gage data is thoroughly modified in stream flow. A drainage area of 10,000 square miles has a collecting surface 805,000,000,000 times greater than an 8-inch rain-gage. Ground storage aids in equalizing unequal distribution of rain as to place and time. An example of the equalizing effect of drainage areas on a huge scale is furnished by the Amazon River. Flowing along the Equator, its northern and southern tributaries are alternately in flood during the first and second half of the year, so that the flow of the main stream is equalized throughout the year (**24**).

In addition to the equalizing effect of large drainage areas, ground and lake storage, the river functions as an amplifyer of the variations of annual rainfall. This is illustrated in the examples of Figure 1, giving the relation between annual rainfall and run-off. As examples are chosen the Ausable River, in Michigan, compiled by the writer, and the Devil Canyon watershed in California, given by *Sonderegger* (**25**). The run-off increases faster than the rainfall; a variation of one-third in rainfall may double the run-off, the latter increasing *three times faster* than the rainfall. The river functions exactly in the manner of an amplifying radio tube, the characteristic curves having the same shape.

On account of these fundamental differences between hydrographic and weather data, the importance of climatic cycles, such as the Brückner and the 11-year cycle, is not to be found in meteorology, but in hydraulic engineering. It is measurable with current meter and surveying instruments rather than with thermometer, barometer, or rain gage.

These fundamental differences are still overlooked in hydraulic engineering. Supposedly in accordance with the great measure of fortuity prevailing in the ceaseless weather changes, a fortuitous sequence of stream flow has been adopted in hydraulic engineering. The actually existing amplification of the small secular changes due to the cumulative nature of hydrographic data is not clearly recognized. Because the climatic cycles thus far found were, rightfully, disregarded in practical meteorology, they were also disregarded by the engineers, although the conditions are fundamentally and totally different.

The difference was carefully noted, however, by Professor Brückner. In Chapter IX of his work, Klimaschwankungen seit, 1700, he discusses the "theoretical and practical importance of the climatic cycle." In this chapter only hydraulic phenomena and activities covered by hydraulic engineering are quoted as examples illustrating the importance of the climatic cycle.

Brückner describes the secular changes in glaciers, lakes, and swamps; the number of floods; channel depth for interior navigation; ground water and sanitation; agriculture, especially in the semiarid regions. These subjects are covered by drainage, sanitary, irrigation, rivers and harbors engineering. In Alpine countries glaciers are now carefully studied by hydroelectric engineers.

The remainder of Chaper IX contains a scientific discussion of the changes in level of oceans, the choice of climatological mean values, and of existing literature. It is significant that the erudite and ingenious author of Climatic Changes thus demonstrated that the cycle which he found by studying the records of 804 stations and 36,900 observation years is principally of importance in hydraulic engineering. Although it has no value for the meteorologist in forecasting the weather, the old work of Brückner, newly interpreted and properly applied becomes a veritable handbook for the hydraulic engineer,

4. IDENTITY OF THE BRÜCKNER CYCLE.

The interpretation referred to involves the relation. between the climatic and solar cycle. Finding successively a cycle in lake levels, rainfall, pressure, and temperature, Brückner naturally suspected the cause of these to be solar variation. Investigation of such relation began shortly after the discovery of the solar cycle by Schwabe. Brückner quotes 36 authors on the relation between solar and terrestrial cycles. Since then the number has greatly increased, but no unanimous verdict has been reached.

Brückner recognized the existence of several long cycles. "Three systems of oscillations exist which are superimposed upon and interfere with each other * * *" (p. 323). He also states that the longest one is a "diluvial" cycle; only the two others control historic times. However, using only a statistical compilation of 5-year averages, he does not find a relation with the Wolf numbers. He states, nevertheless: "I do not deny the influence of sun spots on weather. On the contrary, the above table shows distinctly that influence in certain details although the longer variations seem independent * * *. Much speaks for the theory discussed above, that this force resides in the sun, that therefore the solar radiation shows a 36-year period independent of sun spots. It may cause surprise that such oscillations of solar radiation hitherto have escaped attention; at least I do not know of any phenomena on the solar disk having a period of 36 years. But the measurement of solar radiation is at present (1890) still very imperfect. We even can not demonstrate differences which are known to exist and can be computed. The quantity of heat received on earth is one-fifteenth greater in perihelian than in aphelian, yet this difference has not yet been measured. How much easier, then, could a secular difference in intensity have escaped attention, the amplitude of which is probably less than that and the duration many decades?"

The difference which Brückner finds between his own figures and the Wolf numbers is only apparent. It is mainly due to his exclusive use of 5-year averages, which is insufficient to segregate the cycles. In a previous study (**26**) agreement between the two was illustrated with several examples. It is of interest to further examine Brückner's own figures of wine harvest and temperature. The curves are platted in accompanying Figure 2. By using the previously given method (**26**) they can be segregated into the "Brückner cycle" and the "secular cycle," as shown. It may be seen that with a slight displacement of the wine-harvest curve which Brückner already noted, both are in satisfactory agreement.

In Figure 3, which is an extension back to 1750 of Figure 3, page 293, M.W.R. 1926, these curves appear to run parallel with the Wolf numbers. Brückner does not segregate the Brückner from the secular cycle, and hence his length of period is different. He designates the interval 1756–1805 as one period, whereas in reality it consists of two periods of the Brückner cycle, but only one of the secular cycle. He arrives in this manner at a greatly varying length of the Brückner cycle.

Prior to the platted records Brückner derives his length of period from mere tabulations of "cold" and "warm" periods, which should be regarded uncertain. Adopting

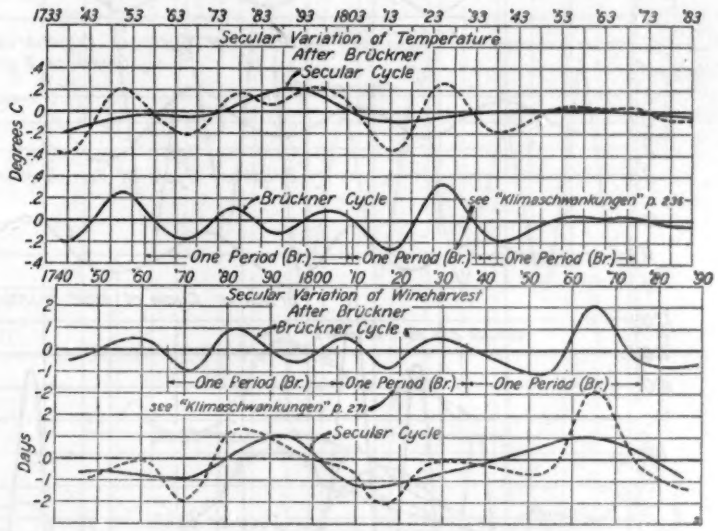
1733 '43 '53 '63 '73 '83 '93 1803 '13 '23 '33 '43 '53 '63 '73 '83
Secular Variation of Temperature
After Brückner
Secular Cycle
Degrees C
Brückner Cycle
see "Klimaschwankungen" p. 236
One Period (Br.)
One Period (Br.)
One Period (Br.)
1740 '50 '60 '70 '80 '90 1800 '10 '20 '30 '40 '50 '60 '70 '80 '90
Secular Variation of Wineharvest
After Brückner
Brückner Cycle
One Period (Br.)
One Period (Br.)
One Period (Br.)
see "Klimaschwankungen" p. 271
Seculsr Cycle
Days

FIGURE 2.—Brückner's figures of temperature and wine harvest

the above separation of the Brückner and secular cycle, the average length since 1770 is 24.5 years; since 1860, 22.6 years.

The 22.6-year period seems to become the accepted solar cycle instead of the 11-year cycle; striking is the great regularity of the cycle since 1860, as pointed out by *Abbott* (**3**). Also, we have since 1860 three times a *high* 11-year maximum following a *low* 11-year maximum. This has been referred to by *Clements* (**3**).

But is this reversal of polarity permanent? Prior to 1860 the alternately high and low maximum of the 11-year cycle is lost. Whether this is due to greater uncertainty of the Wolf numbers prior to 1860 or to an "evolution of the law," as discussed by the celebrated mathematician, *Henry Poincaré* (**31**), will be decided in the future. Should the permanency prove true, then the Brückner cycle is the polarity cycle of the sun spots, superimposed on the secular cycle.

The secular cycle is also variable. From all data available the three last periods are estimated 70, 60, and 90 years in length, or an average of about 73 years. The first period is derived from Douglass's sequoia curve (1911, 11 trees).

While Brückner, with much ingenuity, has sought to systematize the climatic oscillations of long duration, it appears that the conditions are not as simple as he describes them. The alleged reversal of the cycle over the oceans can not be generalized. Undoubtedly the Gulf Stream has much to do with the reversal of the cycle over the oceans as he found, for, while existing on the west and east shore of the Atlantic, it is absent along the California coast. Apparently the Brückner cycle changes phase with geographical location in greater measure than he found.

Since Brückner's time 40 more years of observation are available, but still more are required to properly establish the relations here discussed. The above should therefore be considered tentative and subject to future confirmation.

As Brückner already emphasized, the phase of the climatic cycle varies with geographical location. This beach will cause numerous secondary waves and ripples The division into continents and oceans, warm and cold ocean currents, plateaus and mountain ranges, influence the course of atmospheric circulation. A standard regimen of circulation can be visualized only as existing within wide limits. The records indicate greater regularity in those from plains than from mountainous regions.

Such a standard system of multiannual oscillations is submerged in the daily weather changes, but becomes apparent in the cumulative effects of run-off and storage. While meteorologists, therefore, rightfully claim that a relation between sun spots and weather has not been successfully demonstrated, that claim can not be transferred to hydrographic records. These, often in unison with the Wolf numbers, display oscillations of far-reaching economical importance, which follow a course apparently (but only apparently) independent from the also economically important weather changes with their ceaseless succession

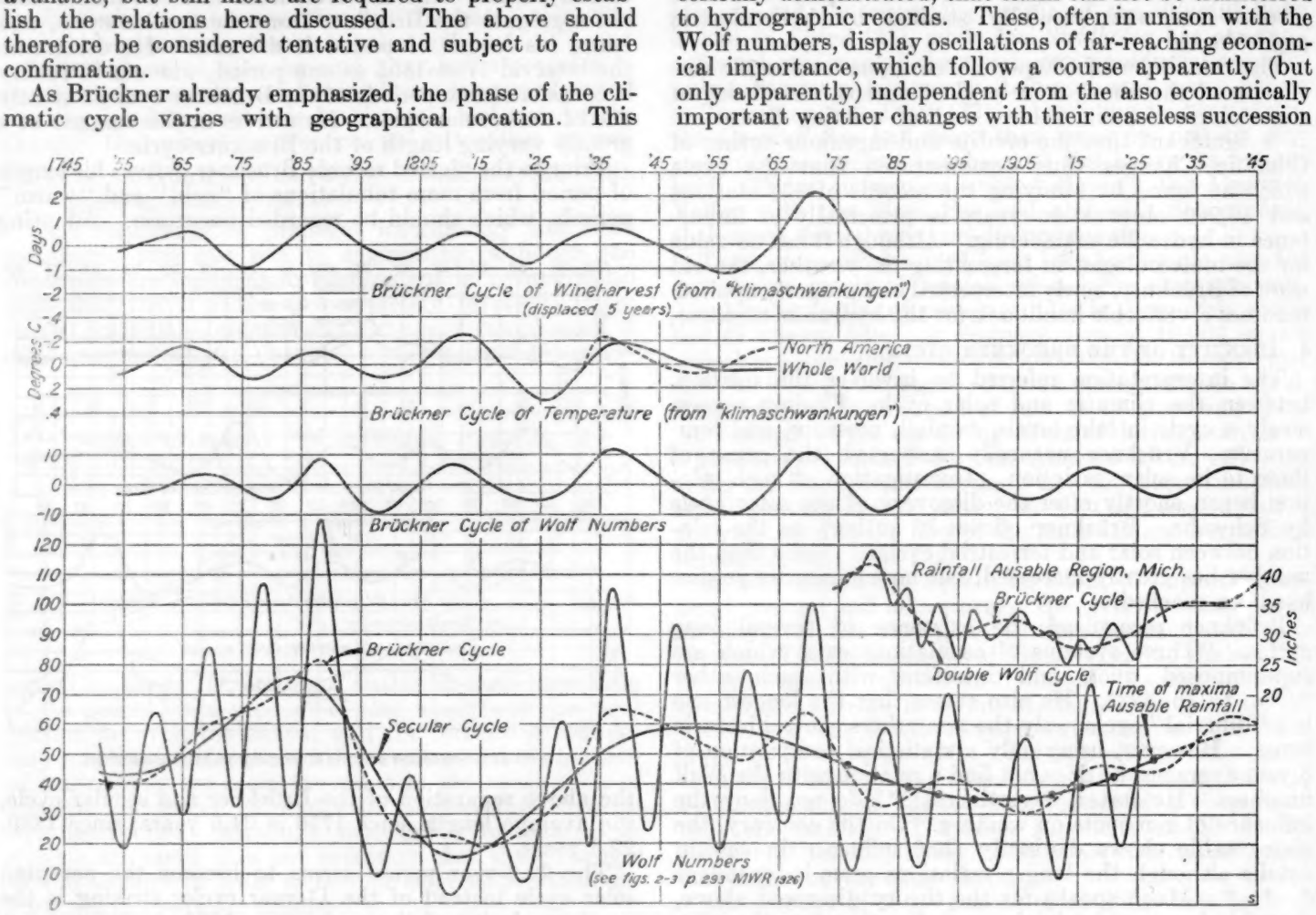
1745 '55 '65 '75 '85 '95 1805 '15 '25 '35 '45 '55 '65 '75 '85 '95 1905 '15 '25 '35 '45
Days
Brückner Cycle of Wineharvest (from "klimaschwankungen")
(displaced 5 years)
Degrees C.
North America
Whole World
Brückner Cycle of Temperature (from "klimaschwankungen")
Brückner Cycle of Wolf Numbers
Rainfall Ausable Region, Mich.
Brückner Cycle
Double Wolf Cycle
Time of maxima Ausable Rainfall
Inches
Brückner Cycle
Secular Cycle
Wolf Numbers
(see figs. 2-3 p 293 MWR 1926)

FIGURE 3.—Correlation of Wolf numbers and Brückner's data

seemingly is in accordance with the results of *Kullmer*, who shows the path of cyclones to vary with the solar cycle (**32**).

In a previous study it was shown that not only the Brückner cycle can be identified in the Wolf numbers, but the smaller cycles as well (**26**). Besides the two cycles named above, the *11-year*, the *"double sun-spot cycle"* (after Douglass) of half that period, and the *"Clough" cycle* are the fundamental units to be found in nearly every record. The latter can often be separated into two cycles of nearly one-quarter and one-eighth of the 11-year cycle; but this is of no practical importance.

It should not be inferred that a universal and rigid applicability should be attributed to this conception. In some regions the relations are clearer than in others. A stone thrown into a quiet pond will cause a concentric and symmetric wave, but the irregularities of an adjacent of frosts, hot and cold waves, rain, hail, snow, and thunder storms, droughts, and cloud-bursts. The latters' hectic succession is merged into a residual system of slow but certain sequences, which at least in some regions can be correlated clearly with the Wolf numbers.

5. EFFECTS OF THE CLIMATIC CYCLES

The lake and ground-water levels rise and fall with these cycles. The Great Salt Lake (fig. 4) is again nearing a period of expansion similar to that prevailing between 1860–1875. An increase in area of some 400 square miles around 1945 may well be expected. The damage thereby caused to riparian owners, to roads, bridges, quays, wharves, and docks is obvious. Riparian structures are usually erected oblivious of the slow but sure rise and fall of the water level, which are not apparent to the uninformed. Only in locations where the limits occur

frequently, as happens along the rivers, are they heeded. The trestle of the Southern Pacific Railroad across the Great Salt Lake will probably have to be raised, as well as the structures of bathing resorts near Salt Lake City.

The Great Salt Lake began to rise simultaneously with the extension of the Mormon settlements in Utah. *Cyrus Thomas* and *Hough* (**27**, pp. 71 and 92) ascribed the improvement of climate to agriculture. The rivers and brooks feeding the lake carried more water than usual; a greater amount could be diverted for irrigation purposes. This was supposedly due to increased area under cultivation, causing increased evaporation and consequently rainfall. The theory proved false when after 1875 the lake fell continuously until 1905, and the irrigated area had to be reduced. Since then the lake has risen, and the next period until around 1945 will probably be characterized by improved grazing and farming conditions all through the arid West.

Typical for the last downward swing of the secular cycle, beginning around 1875, minimum around 1905, and next maximum probably around 1945–1950, is the following opinion based on extensive observation during the last 25 years (**28**):

> Prior to the advent of the white man erosion was a matter of minor importance in the arid Southwest. At that time there was generally an excellent grass carpet which retarded run-off and prevented erosion. Overgrazing by the cattle and sheep industry has depleted, in fact, almost exterminated, the grass carpet over large areas, resulting in erosion and denudation. Rapid restoration of overgrazed areas has taken place during a series of wet years following a series of dry years. * * *

Kirk Bryan (**29**), finding geological evidence of erosion long before overgrazing by the white man's cattle, states: "It appears that these cyclic changes have a common and doubtless climatic cause. The introduction of livestock and the ensuing overgrazing should be regarded as a mere trigger pull, which timed a change about to take place." At the desert border a persistent, cumulative though small deficiency of rainfall just below the necessary minimum gradually overcomes the tenacity of life of the vegetation. Plant life perishes, followed by wind erosion, denudation, and desolation. This undoubtedly is hastened but not caused by overgrazing.

Brückner states: "During minima the dry and warm years will be somewhat more frequent than the moist and cool ones. A forecast of this cycle is of no significance for Europe, as here the variations of rainfall, which are of principal importance, are rather moderate. Of value such forecast would be for the continental regions, where the variations of rainfall are much more accentuated; for Siberia, Australia, and, above all, for the interior of North America." Brückner also gives statistics to show that while in the continental regions the wet period of the Brückner cycle accelerates agriculture, the reverse effect occurs in the normally humid maritime climate of Europe.

The Great Lakes exhibit the Brückner cycle in close agreement with the rainfall; but as the lake level is proportional to the total inflow, the cycle of lake level lags one-quarter period against the cycle of rainfall. The 11-year cycle, of small amplitude in the rainfall of these regions, again is enlarged in the lake levels. At present a maximum prevails; the next maximum, expected to occur around 1940, will, on account of the rise in the Brückner cycle, probably be about a foot higher than the present maximum.

In this region the practical consequences of the faint cycle in climate are measurable in millions of dollars. The value of 1 foot additional draft to navigation is estimated at $5,000,000 (**30**).

Prior to 1925 the continually falling lake level caused widespread damage and was repeatedly investigated and reported upon. This continued damage finally caused six States and the Dominion of Canada to prefer legal action against the city of Chicago, the Chicago Drainage Canal supposedly having caused the lowering of the lake levels. The cost of this legal struggle and the resulting compulsion of the city of Chicago to build the largest sewage-disposal plant in existence represent huge expenditures.

Private owners, real-estate enterprises, large industrial concerns, as well as municipalities along the 5,400 miles of shore line of the Great Lakes, suffered great damage on account of the rise in the lake level since 1925. Not guided by "climatic engineering," construction activity crowds against the existing shore lines, following these in their slow advances and retreats, and occasionally falls into the "climatic trap." In certain sections the spectacle of new residences surrounded by water is frequently seen. A large lumber concern was forced to abandon its yards.

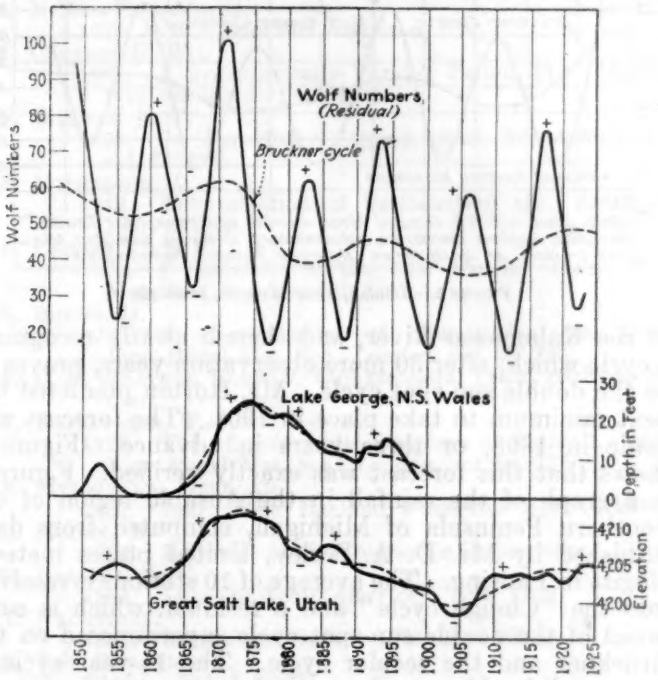

FIGURE 4.—Great Salt Lake, Lake George, Australia, and Wolf numbers

In another city a large public-utility corporation installed at great cost a booster pumping plant for the circulating water of its superpower station, but due to subsequent rise in level the large investment was never used. The varying yield of streams also affected water power. Another public utility, fearing continuation of the dry years prior to 1926, hurriedly installed additional boiler capacity to take care of the reduced hydroelectric output, but the large investment proved superfluous for the original purpose.

Such are the far-reaching effects of faint cycles in climate, having an amplitude of no importance in daily weather service.

6. APPLICATION OF CORRELATION WITH WOLF NUMBERS.

Seth B. Nicholson (3) advocated the use of the Character Figures of Solar Phenomena, published in Zurich, instead of the Wolf numbers, for comparison with terrestrial cycles. According to Mr. Nicholson, the Wolf number is equal to the number of spots plus ten times the number of groups; and it should therefore not surprise the investigator of cycles that such an arbitrary constant

should fail to give consistent results throughout. Nevertheless, a surprising agreement with terrestrial cycles may be found in some records.

The unbroken sweep of open country in the Great Lakes region seems especially favored with a regular system of atmospheric circulation. From the rain-gage readings of the United States Weather Bureau the cycle was derived already 30 years ago by the prominent hydrologist, Robert E. Horton. In Water-Supply Paper No. 30, 1899, Mr. Horton discusses run-off and water power

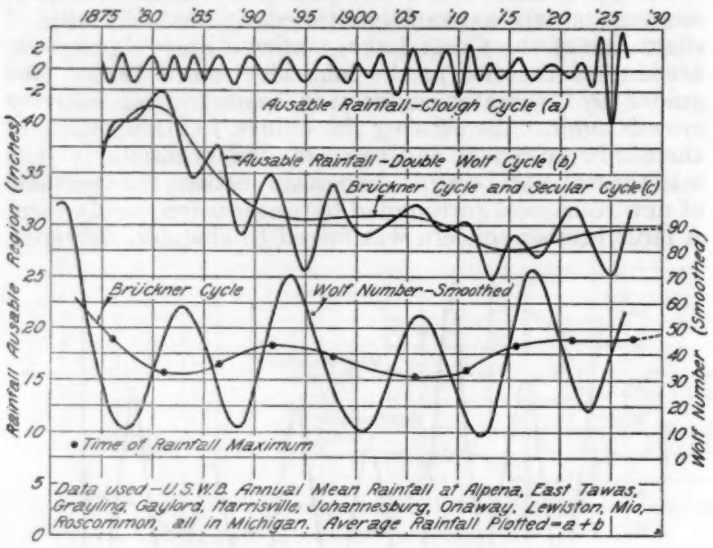
1875 '80 '85 '90 '95 1900 '05 '10 '15 '20 '25 '30
Ausable Rainfall–Clough Cycle (a)
Ausable Rainfall–Double Wolf Cycle (b)
Brückner Cycle and Secular Cycle(c)
Brückner Cycle
Wolf Number–Smoothed
• Time of Rainfall Maximum
Rainfall Ausable Region (Inches)
Wolf Number (Smoothed)
Data used–U.S.W.B. Annual Mean Rainfall at Alpena, East Tawas, Grayling, Gaylord, Harrisville, Johannesburg, Onaway, Lewiston, Mio, Roscommon, all in Michigan. Average Rainfall Plotted=a+b

FIGURE 5.—Rainfall, Ausable region, Michigan

of the Kalamazoo River, and therein clearly recognizes a cycle which, after 30 more observation years, proves to be the double sun-spot cycle. Mr. Horton predicted the next minimum to take place in 1901. The forecast was made in 1898, or three years in advance. Figure 5 shows that this forecast was exactly verified. Figure 5 is a graph of the rainfall in the Ausable region of the Southern Peninsula of Michigan, computed from data furnished by Mr. D. A. Seeley, United States meteorologist in Lansing. The average of 10 stations is resolved into the "Clough cycle" and a residual, which is composed of the double sun-spot cycle superimposed on the Brückner and the secular cycle. The 11-year cycle is very small in this record.

It should be emphasized that an average of many stations is needed to eliminate fortuitous errors, distributed, according to Hann, over an area not more than 200 miles in diameter. The Ausable watershed is only some 1,600 square miles.

It may be seen that the cycle discovered by Horton has faithfully recurred since 1899. Indicating the maximum of rainfall on the secular cycle of the Wolf numbers with a black dot, it may be seen that this occurs always before each maximum or minimum of the 11-year cycle. It has faithfully recurred ten times during the last 54 years. We have here in reality a double sun-spot cycle.

Transferring the cycle to Figure 3, the inverse relation of the Brückner cycle in Wolf numbers and rainfall is distinctly seen. The secular cycle is here, as in every other record always independent of geographical location.

A continuation of these relations in the future, while not known with certainty, is probable. The conclusion may be drawn that around 1940–1950 the rainfall may again have increased 30 per cent up to the values prevailing around 1880. The average run-off will then be doubled. Six water-power plants were built on the Ausable River since 1912, at a cost of some $12,000,000. The output may be expected to increase 80 per cent in the above-named period. The effect on the returns on the invested capital is obvious.

The same increase will be felt over a considerable part of the country, and will materially contribute to a renewed popularity of hydroelectric power, which is now lagging behind steam power on account of the greatly increased economy of the latter.

The double sun-spot cycle in rainfall is, as stated above, amplified in stream flow. Figure 6 shows the flow of the Muskegon River, an adjacent watershed. It may be seen that the double sun-spot cycle is plainly visible. By means of this and other graphs the deficiency of hydroelectric power in 1931 is for one power company computed to be 160,000,000 kilowatt-hours, resulting in an increased expenditure for steam coal of some $500,000 for that year. A deficiency in peak capacity of 20,000 kilowatts is also estimated for that year. This means either a new investment of $2,500,000 or else purchase of power elsewhere.

Nevertheless, the weather changes in 1931 will probably alternate as usual without any apparent connection with the Wolf numbers. The latter's unmistakable connection with stream flow, however, will at the same time influence public-utility engineering to the extent of millions of dollars.

The continuity instead of the fortuity of stream flow enables a close estimate of next year's run-off. As described in MONTHLY WEATHER REVIEW, March, 1928, it is possible to make such estimates by extrapolation. The example there given actually checked within 5 per cent. Another estimate made that year placed the mean flow of the Winnipeg River at Great Falls in 1928 at 55 per cent of that during 1927. It actually was deter-

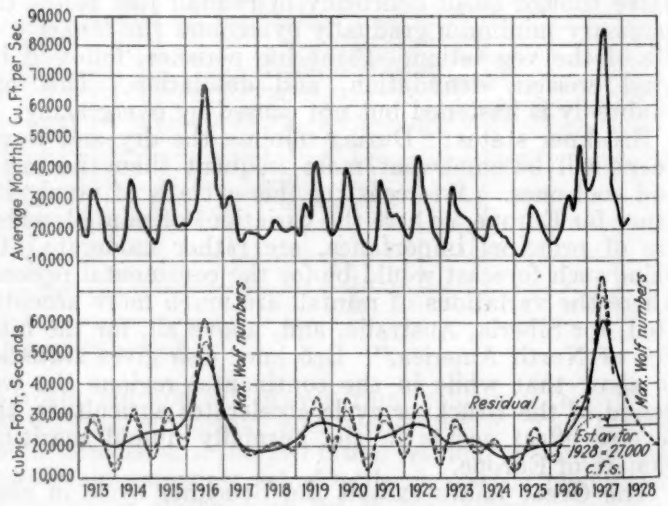

FIGURE 6.—Run-off, Muskegon River, Mich.

mined by the Dominion Bureau of Reclamation and Power to be 60 per cent of that in 1927. The illustration Figure 7 is a graph of the run-off of the Winnipeg River.

Figure 4, the elevation of the Great Salt Lake, the Australian Lake George, and the Wolf numbers, shows likewise close relation with each other. Of interest is the inverse relation of the 11-year cycle in the Wolf numbers and the Great Salt Lake. The graph was made in 1924, and it could then safely be announced that a drop in lake level would take place on account of that

relation. This actually occurred, and a rise culminating in 1936 may well be expected, increasing the lake level at least 4 feet over the present. On account of the simultaneous rise in the Brückner cycle, that figure will probably be exceeded.[1]

Knowledge of the climatic cycles enables the engineer to place a given fragmentary record of stream flow or lake level in its proper relation to the changes occurring during longer periods, and allows an estimate of probable maxima and minima as well as of the probable course in the near future. The old fortuity theory should be

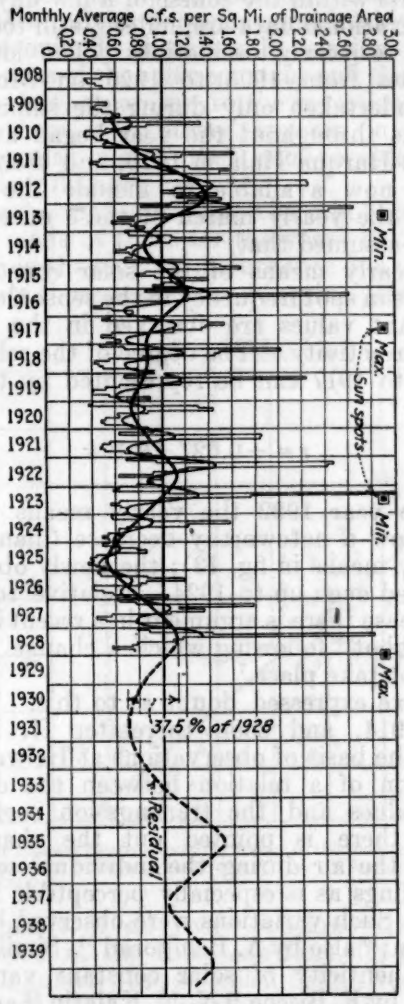

FIGURE 7.—Run-off, Winnipeg River, Canada

replaced by the truer conception of recurrent cycles, which in many locations afford quantitative estimates of future conditions involving large expenditures or investments.

SUMMARY

(1) Recent climatic changes have too small amplitudes to be of any importance in forecasts of weather. Due to the cumulative as well as amplifying nature of stream flow, they are of great importance in hydraulic engineering.

(2) Correlation of the Wolf numbers and weather is not accepted by many leading meteorologists. Correlation between Wolf number and stream flow, however, can be shown as well as utilized in engineering projects involving large investments.

[1] The following has been communicated to the editor in a private communication: "I just received from Brisbane, Queensland, the data of the Australian Lake George to date. Remarkably enough, the parallelism with the elevation of the Great Salt Lake is preserved to date. Lake George was dry ground 1905, and is at present more than half full. I also received rainfall data from there which not only show the double Wolf cycle as plainly as Michigan does, but the small amplitude of that cycle around 1905–1910 also occurs in Australia."

[Discussion of this very interesting paper on the part of hydraulic engineers is invited.—EDITOR.]

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RADIATION AND TEMPERATURE OF THE SUN

By W. E. BERNHEIMER

OSCILLATIONS OF THE SOLAR CONSTANT [1]

General statement.—When we now take under consideration the question of the oscillations of solar radiation it can be, from the astronomical point of view, only a matter of investigating the changes in radiation that have their origin in the sun. There is, therefore, in the first place a question whether all disturbing influences are thoroughly eliminated in the observational material at the present time. In so far as this is not the case such oscillations in solar radiation afford occasion for a series of interesting meteorological phenomena, upon which we naturally can not enter in this manual.

Apart from rather short series of observations from Potsdam, Davos, Helwan, Warsaw, Upsala, and Pavlovsk, almost all of the available data are due to the work of the Smithsonian Institution. Through this unusual circumstance it results that in a statement of the problem there appear on one side a great number of writers who raise objections to the reality of the oscillations, and to whom there is opposed only one defender. Despite this there will be an attempt to give an objective survey of the present status of the problem.

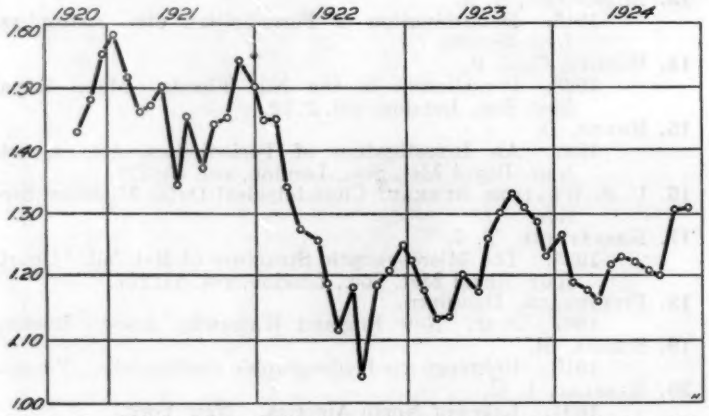

FIGURE 13.*—March of the monthly means of the solar constant from October, 1920, to November, 1924. (Mean values from Montezuma and Harqua Hala)

Long-period oscillations. Yearly and monthly means.—The first statements which express a suspicion of a change in solar radiation, based on a rather long series of observation, originated in the year 1903. L. Gorczynski [2] demonstrated for the Warsaw observations a decrease in solar radiation from May, 1902, to the end of the year 1903, in agreement with the results reached by Ch. Dufour [3] in Switzerland. According to S. P. Langley [4] the decrease in radiation at the end of March, 1903, amounted to 10 per cent of the previous value.

If we now follow up the values of the solar constant that were obtained in America, first by Langley and later by Abbot, it appears without doubt that the amplitude of the long-period oscillation decreases materially in the course of the years, with the exception of the year 1912 in which the anomaly is due to the eruption of Katmai. During the same time there was success in attaining considerable advance in refinement of methods of observation.

In considering the observed oscillation of the solar constant a differentiation must be made between those longer periods, which manifest themselves in the march of the yearly and monthly means, and those of a short-period nature, which show oscillations in the results of measurements within the course of a few days.

The observational data are, indeed, still too scant for a decision as to yearly oscillations. The long series of measurements from 1905 to 1920 on Mount Wilson could be undertaken only during the summer months. Observations throughout the year began at Calama in 1918 and at Harqua Hala in 1920, and their provisional results are now available to include the year 1924. Relative to the yearly march of these measurements it is generally assumed that:

1. The yearly means of the solar constant show a march with sun spot frequency in the sense that the higher solar constant values are observed in the years of increased solar activity. The degree of the relation for the years 1905 to 1917 can be represented by the following correlation: [5]

$$r = +0.627 \pm 0.124$$

2. In the year 1922 the yearly means of the solar constant show a noteworthy decrease (manifest also in the monthly means in fig. 13); the newly obtained value is maintained even up to 1924. Relative to the reality of this decrease there is argument in a recent investigation by C. G. Abbot,[6] following which a change in reduction scale did not take place.[7]

Many have expressed doubt as to this. T. L. Eckersley [8] in 1914, and soon thereafter H. Knox-Shaw,[9] mainly on the basis of observations at Helwan, expressed the suspicion of a relation between the derived solar constant values and the transmission coefficients. As the cause there is pointed out the changing transparency of the air during the individual series of bolometric readings as is especially perceptible in the morning hours. Such variations were observed by G. Muller and E. Kron;[10] also by A. Bemporad.[11] Similar objections to the authenticity of solar constant variations have been raised by F. Biscoe,[12] N. N. Kalatin,[13] and E. Stenz.[14] G. Granquist [15] gave special attention to this question and disclosed especially for the Mount Wilson values for 1905–1908 and 1909–1911 a relation between solar constant and transmission coefficient. In 1924, W. E. Bernheimer [16] investigated all of the Mount Wilson data, especially the monthly means from 1905 to 1920,

* The original numbering of the figures is followed.

[1] *Strahlung und Temperatur der Sonne. Handbuch der Astrophysik. Band IV. Berlin, 1929.*

[2] Comptes Rendus. 138. (1904.) p. 255.

[3] Comptes Rendus. 136. (1903.) p. 712.

[4] Astrophysical Journal. 19. (1904.) p. 305.

[5] A. Angström, *Geografiska Annaler.* 1921. p. 162. See also W. E. Bernheimer, *Seeliger-Festschrift.* 1924.

[6] Gerlands *Beiträge.* 16. (1927.) p. 344.

[7] NOTE.—See C. G. Abbot. A group of Solar Changes. Smithsonian Miscellaneous Collections. Vol. 80. No. 2. (1927.) On page 6, Table 2 gives corrections to apply to solar constant values to bring them to the Mount Wilson scale of 1905–1920. From Jan. 1, 1923, to Jan. 1, 1924, it varied between +0.020 and +0.010; and between Feb. 1, 1924, and Apr. 30, 1925, between −0.002 and +0.008.

[8] Helwan Observatory. Bulletin No. 14. 1914.

[9] Helwan Observatory. Bulletins Nos. 17 (1915), 23 (1921), and 30 (1924).

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[11] *Memorie della Societa degli Spettroscoposti Italiani.* 6. 1921.

[12] Astrophysical Journal. 46. (1917.) p. 355.

[13] *Nachrichten des physikalischen Hauptobservatoriums.* Petrograd. I. Nr. 2. 1920.

[14] *Circutaires. Observatoire de Cracovie.* 15. 1923.

[15] *Meddelanden fran Vetenskapsakademiens Nobelinstitut.* 5. Nr. 1919, and *Kosmos Fysiska Uppsatser, Svenska Fysiker-Samfundet.* Stockholm. 1921.

[16] *Seeliger Festschrift.* 1924. p. 452.

and was able to show that for the entire period such a relation is to be demonstrated. This relation is reproduced in Figure 14.

Later investigations by C. G. Abbot [17] seek to establish the usefulness of the Mount Wilson values, but they reveal, meanwhile, that the measure of the oscillation observed there is reduced to half value. These results obtained by Abbot are represented in Figure 15. In similar manner the latest, as yet unpublished, monthly means for Montezuma have been evaluated. We shall return later to the new process of "Selected Pyrheliometry" introduced for application in this evaluation.

The state of affairs becomes considerably complicated in that not only do there result relations between the monthly means of the solar constant and the transmission coefficients, but, according to the investigations of C. F. Marvin,[18] there straightway appears in the monthly means a regular march that can be referred only to atmospheric influences.

The data from Mount Wilson used in Figure 14 (exception being made of those for the years 1912 and 1913 in order to avoid the unusual disturbance due to the Katmai eruption) are those treated by Marvin. He arranges the

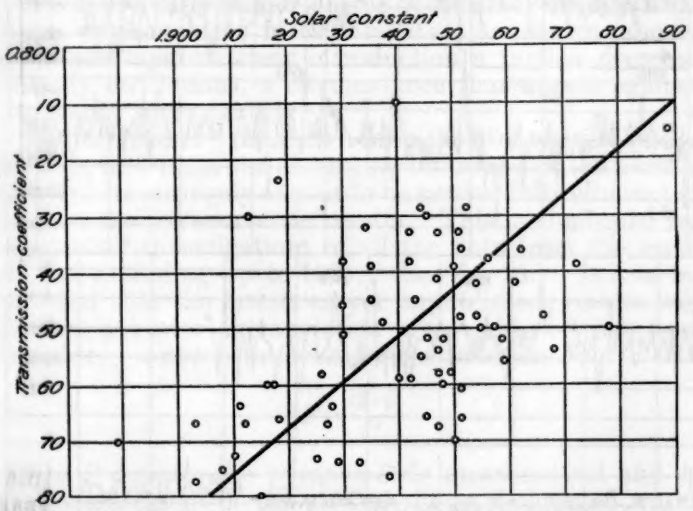

FIGURE 14.—The relation between monthly means of the solar constant and the synchronous transmission coefficients observed on Mount Wilson in the period 1905–1920 (after Bernheimer)

monthly means of all years continuously and plainly finds a period in the solar constant depending on the season. Singularly, the so-called definitive values of the solar constant show, after the application of the water vapor correction, the yearly march as still more pronounced.

This unexpected result would argue that the water vapor correction is not only insufficient, but even influences in an unfavorable sense the radiation values obtained after extrapolation. For the explanation of this special question still more exhaustive investigations must be set on foot. Also in the bolographic measurements at Calama from 1918 to 1920 there appears a dependence of the solar constant on the season of the year; this is indicated, however, only in a moderate measure. This series can, therefore, be looked upon as the best and least distorted. In later years the effect enters again in full force, just as on Mount Wilson. Here it is a question of the monthly means from pyranometric measurements at Calama and Montezuma from 1919 to 1924, represented in Figure 16. This is all the more remarkable since these results are based on observations according to the so-called "Short Method," a method that in and of itself should lead to increased accuracy.

As is seen from Figure 16, Marvin could easily represent the march of the monthly means by a sine curve. The clearly defined seasonal effect is manifested in that the monthly means of the solar constant were observed to be higher in the summer condition (September to February) and lower in the winter condition (March to August) of the atmosphere.

Relative to the monthly oscillations of the solar constant a summarization may be made to-day about as

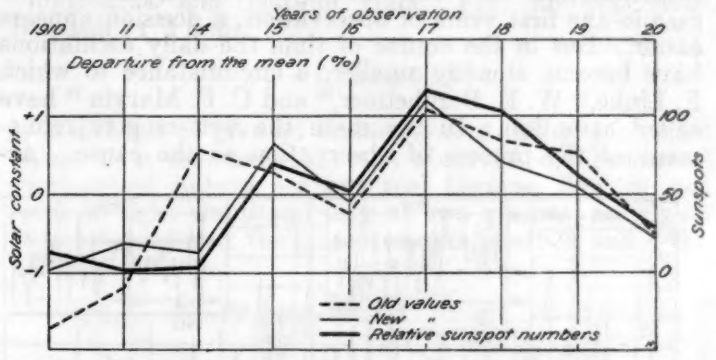

FIGURE 15.—July observations on Mount Wilson in the period 1910–1920. Observed oscillations of the solar constant according to the old method and results according to the new process of "Selected Pyrheliometry" compared with sun-spot frequency (after Abbot)

follows: A number of writers have demonstrated a dependence of the monthly means of the solar constant on transmission coefficients, thus on the condition of the atmosphere at the time. These observations are confirmed by Marvin, who discloses the meteorological cause of this dependence. This fact, however, gives no explanation for the entrance of errors into the extrapolation. So far it is only known that in the bolographic determinations on Mount Wilson careful consideration of water vapor absorption intensifies the inaccuracy of the extrapolation. Then the pyranometric measurements (in which, as is shown later, changes in the condition of the air during a day probably no longer produce

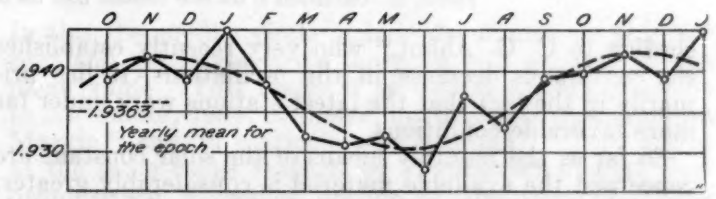

FIGURE 16.—Monthly means of the solar constant from observations on 1,080 days from July, 1919, to July, 1924. (Pyranometric measurements at Calama and Montezuma)

disturbing influences on the solar constant) show unequivocally relations to the atmospheric processes. Pyranometric values were used exclusively, however, in Figure 16.

On the other hand it must be emphasized that changes in the solar constant come to light plainly from year to year. (See, for example, fig. 13.) These changes must naturally be smoothed out in Marvin's method of forming monthly means for a group of years. Although, after consistent verifications, the monthly means of the constant, in so far as they have been published, can by no means be viewed as true values of extraterrestrial radiation, yet, doubtless, if the elimination of the influence of the earth's atmosphere should be attained, there may be

[17] Popular Astronomy. 34. (1926.) p. 574. MONTHLY WEATHER REVIEW. May, 1926.
[18] MONTHLY WEATHER REVIEW. 53. No. 7. 1925.

a remaining oscillation, which is greater than the error of observation and has its origin in the sun itself.

Short-period oscillations.—The difficulties that exist relative to an objective verification of long-period oscillation of the solar radiation are naturally accentuated in the review of changes in the results of measurements from day to day. In the monthly means the short-period oscillations, which are to be referred, at least in part, to instrumental inaccuracies and atmospheric disturbances, are smoothed out, so that in them and still more in the yearly means important changes stand forth more clearly. So long as the short-period oscillations showed such great amplitudes that the percentage errors of determination were considerably exceeded, as was the case in the first years of observation, a decision appears easier. But in the course of time the daily oscillations have become steadily smaller, a circumstance to which F. Linke,[19] W. E. Bernheimer,[20] and C. F. Marvin [21] have called attention. In the main the writers give refinement of the process of observation as the cause. According to C. G. Abbot,[22] who very recently establishes the continuous decrease in the oscillations, it lies primarily in the fact that the latest stations work under far more favorable conditions.

So far as the monthly means of the solar constant are concerned the available material is considerably greater. As with the yearly means so with the monthly means, it is frequently assumed that a decided change is to be noted with sun-spot frequency and, indeed, in the same direction. This relation, however, seems not to be certain, as appears from an investigation by W. E. Bernheimer.[23] To be sure, there results for the Mount Wilson values the expected positive correlation, but with the new stations it becomes infinitesimally small, and shows, as can be seen in Table 1, in part even an indication of an opposite relation. Additional data are, therefore, still necessary.

TABLE 1.—*Relation between the monthly means of the solar constant and the frequency of sun spots*

Period	Number of values	Station	Correlation between monthly means and spot frequency
			r=
1905 to 1920	71	Mount Wilson	+0.415±0.066
1918 to 1920	24	Calama	−0.152±0.134
October, 1920, to September, 1922	24	Harqua Hala	+0.326±0.124
1921	12	Montezuma	−0.209±0.184

On the question of the reality of these monthly means it is to be remarked that it appears as granted when, as already set forth, we have here before us values that actually represent the amount of the solar energy at given times, and so are completely freed from the influences of the earth's atmosphere.

A representation, after Marvin, of values measured on almost 2,000 days in the years 1902 to 1919 is given in Figure 17. Among other things there are noted the marked

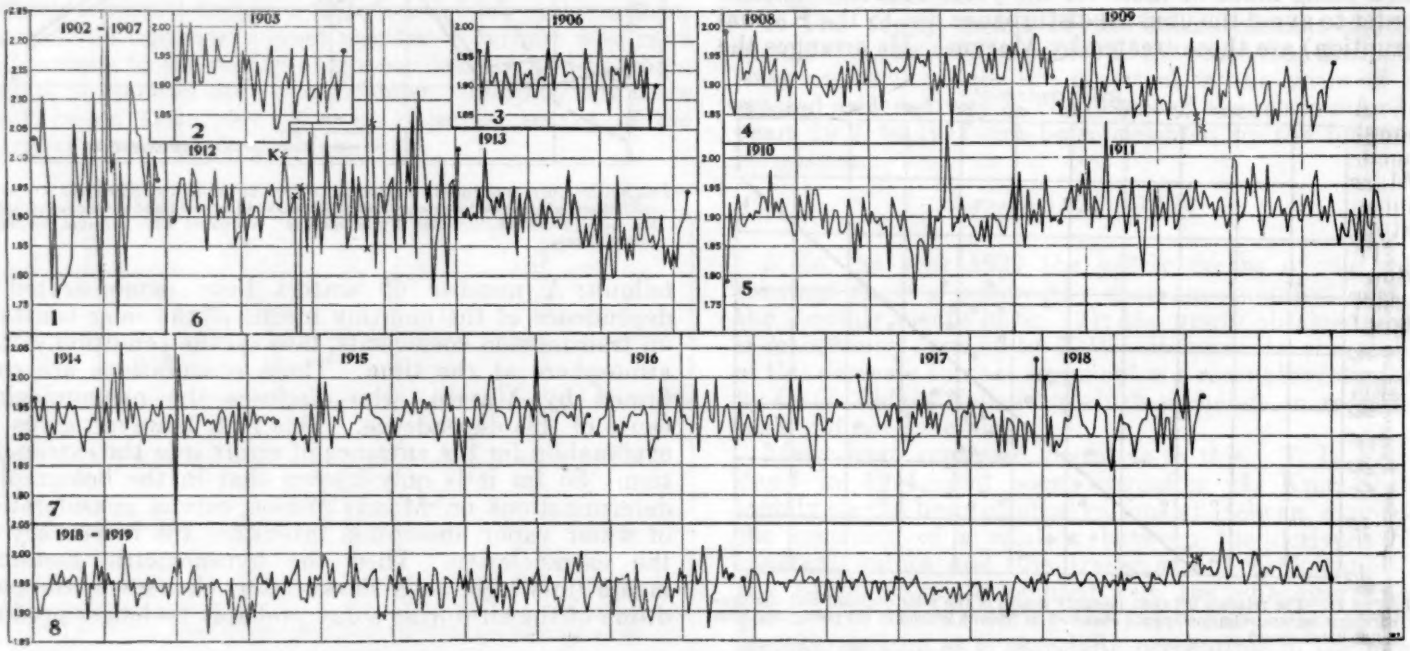

FIGURE 17.—Oscillations of the solar constant from the beginning of observations in 1902 to the end of 1919 (after Marvin)

oscillation that began in 1912 incidental to the Katma eruption, the persistent decrease in oscillation from year to year, and, especially, the striking diminution in oscillation after the middle of 1919, coincident with the introduction of pyranometric measurements.

The decrease is given statistically in Table 2.

TABLE 2.—*Oscillations of the daily values of the solar constant in the different years of observation. The scatter is represented as the probable error in a single day, expressed in percentage of the average value for the whole period, 1.94 g. cal. cm.$^{-2}$ min.$^{-1}$*

Year	Station	Number of days	Amount of scatter
			Per cent
1909	Mount Wilson	96	1.3
1912	Mount Wilson (Katmai)	100	2.2
1913	do	86	1.7
1918	Mount Wilson	56	1.4
1918	Calama	116	.9
1919	Calama, old method	131	.9
1919	Calama, new method	333	.52
January to April, 1922	Montezuma	452	.49
1922 to 1924	Montezuma, Harqua Hala	842	.41

[19] *Meteorologische Zeitschrift.* 41. (1924.) p. 74.
[20] *Verlag von Julius Springer.* 59. 1924.
[21] MONTHLY WEATHER REVIEW. 53. No. 7. 1925.
[22] Gerlands *Beitrage.* 16. (1927.) p. 344.
[23] *Seeliger-Festschrift.* 1924.

The introduction of pyranometric measurements, a process that is designated as the "Short Method," really indicates an important advance. Hitherto the transmission coefficients have been derived bolographically for different wave lengths only in unlike air masses, that is at different times in the course of a day. The series of objections previously made applies to this. The new process makes it possible to obtain the transparency of the air with a single observation when the brightness of the sky H is measured with a pyranometer in the immediate vicinity of the sun and in addition the water vapor correction ρ/ρ_{sc} is determined, as previously, by the measurement of the band $\rho\sigma\tau$. Then the measure of the prevailing transparency is:

$$F = H\rho_{sc}/\rho$$

After the relation of H to the transmission coefficient has been determined empirically for a rather long series of observations, a single measurement suffices for the determination of the solar constant. The last circumstance is a disadvantage to the method since by it there is established a certain connection with the earlier process.[24]

A substantially higher degree of accuracy results from these pyranometric measurements. As shown above, there accompanies their introduction a further decrease in daily oscillations, a circumstance that argues against the reality of variability.

As Bernheimer[25] has shown from the Montezuma values for 1921 and 1922, the disturbing influences of the earth's atmosphere strangely appear to be not yet fully eliminated even in the pyranometric results. This is confirmed by Marvin's [26] investigations of all the data from the same station extending up to 1924. (See fig. 16.) It is to be assumed that the latest, as yet unpublished, results will involve a better extrapolation since Abbot [27] has now introduced a new expression for the function F:

$$F = \frac{H \cdot \psi}{P}$$

where P denotes the pyranometric measurement and ψ, the measurement of the area of the so designated water band. If it is then assumed that the influence of the earth's atmosphere is fully eliminated there yet remains the difficulty, raised first by Linke [28] and later by Marvin, that the oscillations from day to day (which, in the average of 1,400 individual cases, amount to 0.0117 g. cal. cm.$^{-2}$ min.$^{-1}$, or 0.60 per cent of the mean solar energy per year) just equal the order of the accuracy of the pyranometric measurements.

Nevertheless, short-period oscillation can not, for this reason, be denominated generally as impossible. In line with a remark by Abbot [29] it can be said that, although the average departures from the mean of a long series are small, it is still possible that isolated decided departures are not accidental, but real. Simultaneous measurements at two places appear to be especially suited to the examination of such exceptional cases.

Oscillations on the basis of simultaneous measurements at different places.—The relation of simultaneous solar constant measurements was first investigated by Kron,[30] who found a correlation:

$$r = +0.508 \pm 0.071$$

between the results at Mount Wilson and at Bassour, Algeria. For 106 common days in the period 1918–1920 Abbot [31] finds:

$$r = +0.491 \pm 0.500$$

Clayton [32] and Linke [33] also investigated these data. The latter remarks that the relation appears less pronounced only in 1920. In general it can be said, however, that the results up to 1920 show a remarkably concordant march in the simultaneous values of the solar constant.

It is curious that a striking change in the relation occurs in 1921, when for the first time observations are available for all months from the climatically favored stations at Montezuma and Harqua Hala. For the year 1921 Bernheimer [34] finds:

$$r = +0.294 \pm 0.083$$

It is difficult to give an explanation of this phenomenon unless it is assumed that the observed oscillations of short-period nature are not real because they do not come to light simultaneously at two places. In Figure 18 are reproduced the measurements for 1920 and 1921.

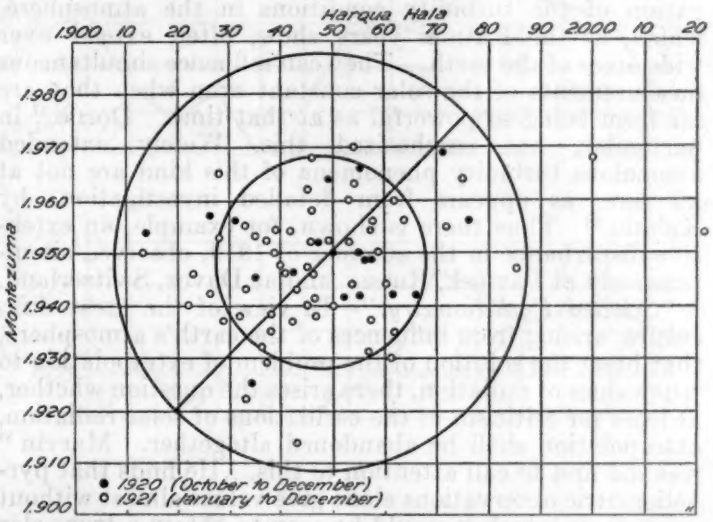

FIGURE 18.—Synchronous values of the solar constant at Montezuma and Harqua Hala (after Bernheimer)

In this the smaller circle include departures up to 1 per cent and the larger circle those up to 2 per cent of the mean value. This material as well as the latest results to November, 1924, inclusive, have been investigated by Marvin [35] and, in particular, by Kimball.[36] They arrive at the same result reached by Bernheimer in that they demonstrate a further decline of the relation. Thus Kimball finds:

TABLE 3.—*Correlations between determinations of the solar constant at Montezuma and Harqua Hala*

Period	Number of days	Correlation
		$r =$
October, 1920, to March, 1922	99	+0.341±0.060
April, 1922, to July, 1923	106	+0.18 ±0.063
August, 1923, to November, 1924	193	+0.17 ±0.045

[24] *Seeliger-Festschrift.* 1924. p. 425 ff.
[25] Ibid.
[26] MONTHLY WEATHER REVIEW. 53. No. 7. 1925.
[27] Gerlands *Beiträge.* 16. (1927). p. 344.
[28] *Meteorologische Zeitschrift.* 41. (1924.) p. 79.
[29] Gerlands *Beiträge.* 16. (1927.) p. 344.
[30] *Verlag von Julius Springer.* 49. (1914.) p. 68.
[31] Annals of the Astrophysical Observatory of the Smithsonian Institution. Vol. 14. 1922.
[32] World Weather. 1923. p. 218.
[33] *Meteorologische Zeitschrift.* 41. (1924.) p. 74.
[34] *Seeliger-Festschrift.* 1924. p. 409.
[35] MONTHLY WEATHER REVIEW, 53. No. 7. 1925.
[36] Ibid.

These results, too, argue very strongly against the reality of short-period oscillations. On the other hand, consideration must be given as follows: Of course, in the dissection of the data alone an oscillation from day to day is investigated, while oscillations of longer period do not come to light. Thus, if the whole period from April, 1922, to November, 1924 (see fig. 13), is considered, there is a certain indication of a relation. When it is considered that in this period solar constant values were obtained on 827 days, of which only 299 were common to both stations, the data are, in the first place, rather scant.

This circumstance, also, renders more difficult the decision as to the reality of the extreme values previously mentioned. In the 827 days a value below 1.900 g. cal. cm.$^{-2}$ min.$^{-1}$ was measured thirty-six times, but only on 6 of the common days; extreme values above 1.940 g. cal. were measured on 35 days, only 4 of which were common to both stations. No decision as to the reality of extreme values of this kind can be reached along this line to-day. The addition of observations from a third station. Mount Brukkaros in South Africa, will be a matter of importance.

Moreover, consideration must be given to the investigation of the turbidity conditions in the atmosphere, which, as the Katmai years show, often extend over wide areas of the earth. They can influence simultaneous measurements of the solar constant even when they are far from being so powerful as at that time. Dorno,[37] in particular, has emphasized this. Widely extended anomalous turbidity phenomena of this kind are not at all rare, as appears from detailed investigations by Kalatin.[38] Thus there is shown, for example, an extensive disturbance in the summer of 1919, observed simultaneously at Pavlosk, Russia, and at Davos, Switzerland.

"Selected Pyrheliometry."—In view of the great difficulties, arising from influences of the earth's atmosphere, that beset the solution of the problem of extrapolation to true values of radiation, there arises the question whether, at least for criticism of the oscillations of solar radiation, extrapolation shall be abandoned altogether. Marvin[39] was the first to call attention to this. He finds that pyrheliometric observations alone give values almost without error, from which it would be easy to obtain a true solar oscillation, especially when observations are made with instruments equally well adapted and at different, entirely independent points in the driest regions of the earth and at different elevations above sea level. For further increase in accuracy measurements could be made simultaneously at each point with two pyrheliometers.

Abbot gave attention to this and, for the investigation of oscillations in solar radiation, developed a new method called by him "Selected Pyrheliometry."[40] In this there is an investigation of the results at Mount Wilson from 1910 to 1920; in a second work[41] the investigation was extended to the observations at Montezuma in 1920–1926. The principle of the method can be analyzed as follows: If it is a question of determining only the oscillations of solar radiation and if absolute values are abandoned, then pyrheliometric observations alone would suffice, provided the observations are so made that the disturbing influences of the atmosphere remain the same at each observation.

Abbot chose observation days when the atmosphere had the same transparency and moisture content. Naturally, also, he combined only those observations with the same elevation of the sun, thus having the same air mass. In this way the changes in transparency in the course of the day play no rôle. In the Mount Wilson data the investigation is limited to the month of July in order to increase the trustworthiness of the results. There was then determined the departure of a July value so obtained from the mean value for all months of July and a comparison was made with departures of the earlier solar constant results from their mean value. The outcome of this test is seen in Figure 15. In general there proves to be the march from July to July as it has resulted in solar constant measurements. In particular it is shown that solar constant oscillations are reduced one-half, as has been set forth previously.

Also in the measurements at Montezuma, in so far as they are known, the process of "Selected Pyrheliometry" appears to promise success. The results indicate a long-period oscillation of the order of about 2.5 per cent. The difficulty in the employment of the method lies in actually finding a sufficient number of days on which there is a corresponding state of atmospheric conditions. At stations specially favored climatically this (correspondence) will be, indeed, rather the case. To what extent the new method can bring a clarification of the question of the existence of short-period oscillations the future will show. It is welcome that provisional results are no longer published and so at the outset there will be submitted for discussion a complete series of final values.

Special oscillations in ultra-violet solar radiation.—The results commented upon in the foregoing sections relate throughout to observed oscillations in the total radiation of the sun. A chief difficulty in the decision as to their reality lay in the fact that it was a matter of relatively small amplitude in oscillations, hence the errors of observation were not very much different in order from those oscillations. The problem is forthwith different when observation is made of special oscillations which exceed in considerable measure the order of the error of observation. This, now, appears to be the case with ultra-violet radiation.

After several preliminary investigations in earlier years, in 1925, Abbot[42] gave his attention in detail to the question as to how far the several spectral regions share in the observed oscillations of total radiation. In the results for 1924 there appears only slight amplitude in changes in total radiation; it is seen almost uniformly in the curve for entire energy; in the short-wave region alone is there indication of marked oscillation. Considerably more striking are the results of investigation of data from 1921 to 1923. As is seen in Figure 13, after high values in 1921 there follows a strong decline in 1922 with minimum to the end of 1924. Abbot arrives at the interesting result that this relatively strong oscillation in the period mentioned comes to light almost not at all in the regions between λ 5,000 and λ 20,000. It is to be ascribed almost exclusively to an oscillation in increasing degree from λ 5,000 to λ 3,500.

This result permits, indeed, a double interpretation: Either the oscillation in the violet and ultra-violet is real and considerably exceeds that in other spectral regions or the oscillations are altogether unworthy of mention and are simulated in the short-wave region by

[37] *Meteorologische Zeitschrift.* 36. (1919.) p. 109.
[38] Gerlands *Beiträge.* 15. (1926.) p. 376.
[39] MONTHLY WEATHER REVIEW. 53. No. 7. 1925.
[40] MONTHLY WEATHER REVIEW. 54. (1926.) p. 191.
[41] Gerlands *Beiträge.* 16. (1927.) p. 344.
[42] Smithsonian Miscellaneous Collections. 77. No. 5. (1925.) P. 25.

changes in the transparency of the earth's atmosphere, especially because of ozone bands.

In 1926 E. Pettit [43] adduced very valuable new data for the investigation of this phenomenon. His investigations consist in comparisons in intensity of radiation at λ 3,100 and at λ 5,000. The measurement was made with thermopiles, in one case through a silver film, in the other through a gold film with a green celluloid filter in front. Measurements with temporary apparatus in four months of 1924 and a definitive series of observations carried out uninterruptedly after April, 1925, gave a maximum of oscillation of ultra-violet radiation at 83 per cent. This value is reduced to 57 per cent since correction had to be applied on account of the reduced permeability of the filter.[44] Later observations were made without the celluloid filter.

The data available to March, 1927, have been investigated in detail by Bernheimer.[45] If the results for 1924 are left out of consideration then observations for two complete years with definitive instrumental equipment show that the highest observed measurement of oscillation amounts to only 26 per cent. In the latest publication [46] Pettit establishes that the march of the oscillations remains essentially unchanged regardless of whether the values are determined for air mass 1 or extrapolation is made to space outside the atmosphere, that is, for air mass 0. This unexpected circumstance led Bernheimer to investigate whether changes in the earth's atmosphere are not reflected in the oscillation. The monthly means of ultra-violet radiation for the two years have a maximum oscillation of 17 per cent and show, in fact, as appears from Figure 20, a decided seasonal march. If comparison is made with the measurements that were obtained photo-electrically at Arosa [47] in the same spectral region and with air mass 2.9, there results an agreeing yearly march, which is to be demonstrated in the same manner also in the transmission coefficients for λ 3,200.

G. M. B. Dobson and D. N. Harrison [48] have recognized a yearly march in the ozone content of the air. Through an investigation Pettit was able to demonstrate that his values for ultra-violet radiation are not materially influenced by the fact that a considerable supposed increase in ozone is assumed from the observed march of the rays. To an increase of 100 per cent in ozone there corresponded a diminution of only 5 per cent in ultra-violet intensity. Pettit comes, therefore, to the conclusion that the strong oscillations observed by him are real and have their origin in the sun.

The strong ozone effect manifests itself principally in a spectral region that lies below that of Pettit. Hence, there can be the opinion that the experiment by Pettit is not conclusive. In reality it appears that the yearly march that occurs in the ultra-violet measurements at Mount Wilson comes out entirely independent of the question of ozone just as (happens) in general turbidity found with total radiation. In Figure 20 this (latter) march is represented in the form of the turbidity factors introduced by Linke.[49]

According to this, high values of ultra-violet radiation occur with clear, winter conditions and low values with much clouded, summer conditions of the atmosphere. In this way there is the temptation to assume that the observed changes in ultra-violet radiation do not take place in the sun, but reflect processes in the earth's atmosphere. On these grounds it is still premature to enter in detail upon indicated relations of oscillations of ultra-violet radiation to ozone oscillations produced by that radiation and to the march of sun spots and solar constant. This is probably all the more the case since, as previously mentioned, according to the investigations of Marvin the monthly means of the solar constant show

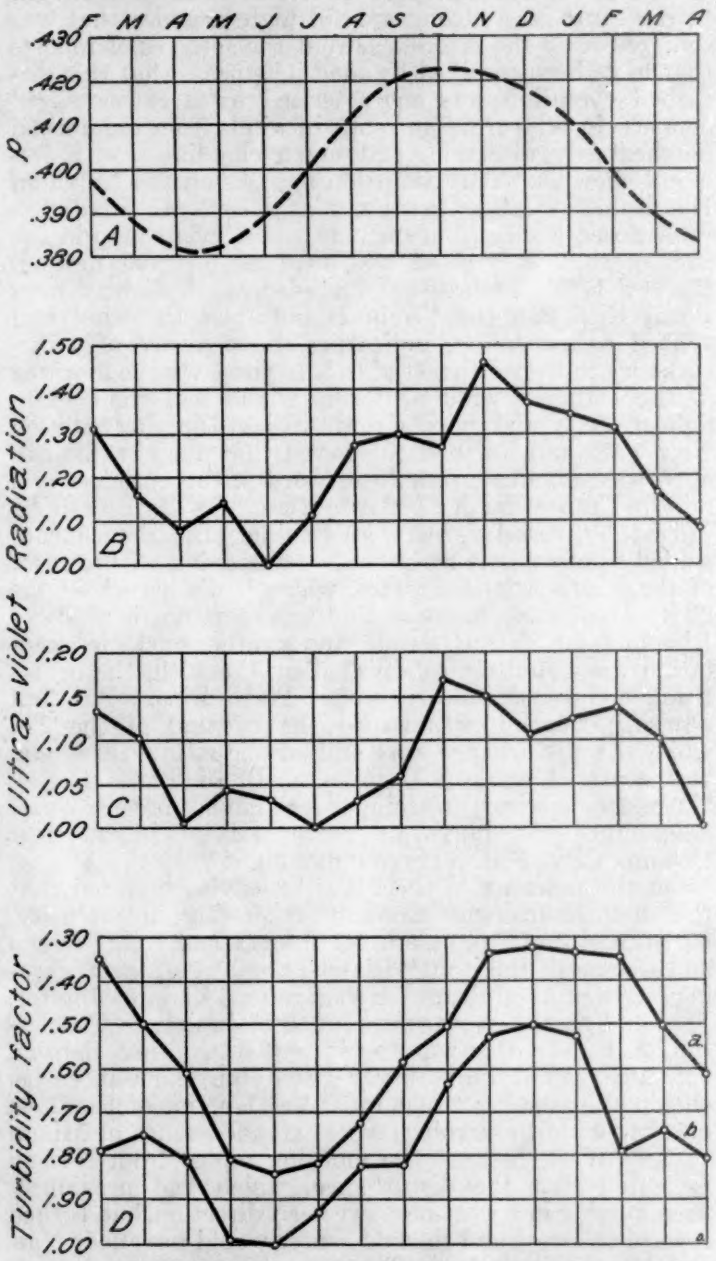

FIGURE 20.—Oscillations of ultra-violet solar radiation compared with turbidity phenomena in the atmosphere of the earth (after Bernheimer)

A. Yearly march of the transmission coefficient for λ 3,200 (Götz). B. Arosa, December, 1921, to July, 1923, ultra-violet radiation of the sum with air mass 2.9. C. Mount Wilson-Tucson, April, 1925, to March, 1927. Measurement of the extraterrestrial ultra-violet radiation (air mass O). D. Yearly march of the turbidity factor of the atmosphere for (*a*) Arosa and (*b*) Upsala.

a dependence on summer and winter conditions of the atmosphere. A decision as to the existence of extra-terrestrial changes in ultra-violet solar radiation could probably be given if the investigations of Pettit were repeated in the Southern Hemisphere. If the oscillations originate in the earth's atmosphere then their march must show a phase shift of six months.—*Translated by W. W. Reed.*

[43] Astronomical Society of the Pacific. Publications. 38. (1926.) P. 21.
[44] Popular Astronomy. 34. 1926. P. 631.
[45] *Die Naturwissenschaften*. 16. (1928.) P. 526.
[46] National Academy of Sciences. Washington. Proceedings. 13. (1927.) P. 380.
[47] F. W. Paul Götz. *Das Strahlungsklima von Arosa*. 1926. Springer. Berlin.
[48] Proceedings of the Royal Society of London. 110. (1927.) P. 660.
[49] *Astronomische Nachrichten*. 221. (1924.) P. 182; *Meteorologische Zeitschrift*. 41. (1924.) P. 74; *Beiträge zur Physik der freien Atmosphäre*. 10. 1922.

THE TROPICAL CYCLONE OF SEPTEMBER 18–OCTOBER 4, 1929

By CHARLES L. MITCHELL

[Weather Bureau, Washington]

The early history of the September, 1929, tropical cyclone is rather obscure. A disturbed condition that apparently originated not far from the Cape Verde Islands about September 11 advanced steadily westward to the south of a strong area of high pressure that was centered near the Azores. From the few vessel reports that have been received by mail it appears that this disturbed condition was characterized by a rather slight decrease in pressure, some shift in winds from the normal northeasterly direction, and much cloudiness with frequent showers. This condition appears on the Northern Hemisphere weather maps not as a cyclonic circulation with closed isobars, but only as a northward loop in the isobars that progressed westward as a wave motion. By the 17th the pressure had decreased slightly over Porto Rico and the Virgin Islands and the wind had shifted to southwest, indicating the presence of a disturbance to the northeast of that region. On the morning of the 18th the wind at Turks Island had changed to light westerly, and reports from two vessels plying between New York and Porto Rico showed that a slight disturbance was advancing northwestward with center several hundred miles north of Porto Rico. So far as can be judged by vessel reports, this minor disturbance continued to move northwestward to a position off the coast of the South Atlantic States, where it dissipated on the 23d. Meanwhile pressure continued low north of Porto Rico and the Virgin Islands, and another cyclonic circulation was definitely established by the 20th, the center being about 300 miles north of Porto Rico. The first advisory warning was issued the evening of the 23d while the disturbance was still of slight intensity, and was centered about 250 miles north of Turks Island. Thereafter advisory warnings were issued at least twice daily until the hurricane center passed inland near Panama City, Fla., on September 30.

On the morning of the 24th the advisory stated that the disturbance was probably increasing in intensity. Upon receipt of 2 p. m. special observations from Nassau and several of the "out" islands, northwest storm warnings were ordered displayed at 5 p. m. Miami to Jupiter, Fla., and northeast warnings north of Jupiter to Charleston, S. C. In this warning it was stated that the disturbance would quite likely reach hurricane intensity within the ensuing 24 hours. At 11 a. m. of the 25th northwest storm warnings were extended south of Miami to Key West, because the morning report from Nassau indicated that the disturbance, which had previously been moving in a west-northwesterly direction, had turned toward the west and that its center would pass near Nassau later in the day. The noon report from Nassau showed quite clearly that the tropical disturbance was moving even south of west—a most unusual direction of movement for tropical cyclones, and especially in the Bahamas—as the barometer was falling rapidly and the wind had backed from west to southwest and had increased from 42 to 50 m. p. h. since 8 a. m. The northeast storm warnings were changed to hurricane at 2 p. m. Miami to Jupiter. At that time it appeared that the hurricane center would reach the southeast Florida coast near Miami the following morning. However, the hurricane was moving more slowly than it had been possible to know from the Nassau reports. A 2 a. m. special observation from Nassau, reporting a rising barometer, with the wind northwest 42 m. p. h., was received the morning of the 26th. This report was quite confusing and could not be verified. Inasmuch as no further reports were received from Nassau for several days and no information was received from vessels near the hurricane center, it was impossible to locate the exact center or direction of movement of the tropical cyclone during the 26th. The advisory warnings of that date, therefore, stated that the future course of the storm was uncertain but that no rapid movement in any direction was indicated during the next 24 hours. It was, indeed, unfortunate that observations were not received from at least two vessels known to have passed through or near the hurricane center. Again, during the 27th the forecaster had to rely entirely on the Cuban and southern Florida reports in attempting to locate the center. The following warning was issued at 9:30 p. m. of the 27th:

> Storm central about 100 miles southeast of Miami, apparently moving very slowly westward, attended by strong shifting gales and probably winds of hurricane force near center. Caution advised vessels Florida Straits and off southeast Florida coast. Wind will likely reach gale force greater part area Jupiter to Key West within next 12 hours, and residents still on exposed keys or islands should seek places of safety.

The morning reports of the 28th indicated that the hurricane was advancing westward through the Florida Straits with center almost due south of Miami. The northeast storm warnings south of Miami to Key West were changed to hurricane at 9 a. m., and northeast storm warnings were displayed north of Key West to Tampa. At 8 p. m. the center was about halfway between Key West and Fort Myers and advancing northwestward over the Gulf of Mexico. Northeast storm warnings were therefore ordered displayed at 9:30 p. m. north of Tampa to Pensacola. The following morning the hurricane center was about 100 miles west of Fort Myers and moving northwestward about 10 miles per hour, and northeast storm warnings were extended to the mouth of the Mississippi River at 10 a. m. During the afternoon of the 29th the following warning was issued:

> Change to hurricane warnings 5 p. m. Apalachicola to Pensacola. Tropical storm still moving northwestward about 10 miles per hour, and its center will likely cross the coast line between Apalachicola and the Mississippi coast some time Monday, attended by winds of hurricane force near center.

The next morning the Apalachicola report was missing on account of disrupted wire communication, but the Pensacola report indicated that the center was about 75 miles southeast of that place and still moving northwestward 10 to 12 miles per hour. Hurricane warnings were extended along the Alabama and Mississippi coasts at 9 a. m. Later reports showed that the center was slightly farther east than indicated by the Pensacola report, and during the day and early part of the following night it curved sharply toward the northeast, passing inland near Panama City at midnight. The storm moved rapidly northeastward, reaching the lower St. Lawrence Valley the morning of October 4, after which it moved eastward across the Atlantic Ocean, reaching the British Isles the morning of the 8th. After this date it merged with another extensive disturbance that was advancing eastward farther to the north.

The path of this tropical cyclone (see Chart III, Monthly Weather Review for September, 1929) was one

of the most erratic and abnormal during the last 50 years, with an exceedingly slow rate of movement during the period September 24–28. On the 24th it was centered some distance northeast of Nassau, and during the 28th it passed through the Florida Straits. During the 3½-day period ending at 8 a. m. of the 28th the storm center moved only about 300 miles, or less than 4 miles an hour, and the greater part of this time its course was toward the southwest, the center on the 28th being 80 or 90 miles farther south than on the 24th. Its rate of movement over the water previous to the 24th and after the morning of the 28th was approximately 10 miles an hour.

During most of September the winds in the altocumulus and cirrus cloud levels were light and variable over the United States, and this condition no doubt existed over the Bahamas region, especially during the 24th to 28th. As a rule, during September the Atlantic high-pressure area much of the time extends westward from Bermuda to the South Atlantic States, but this condition seldom prevailed during September, 1929. This accounts, in a large measure, for the slower air drift toward the west in the region of the Bahamas. Moreover, an air mass moving quite slowly in any given direction will change its direction of movement under the influence of very slight changes in pressure distribution. It is difficult or impossible to detect such slight changes in pressure distribution during September 24–28, but the fact that the tropical cyclone moved toward the southwest during most of this period shows quite clearly that some minor change in pressure distribution, and consequently change in direction of air movement occurred in the higher levels that controlled the movement of the cyclone.

As stated previously, the disturbance was of little intensity until after the morning of September 24. The steamship *Gulf Bird* was near the center in latitude 26° 30′ N., longitude 74° 20′ W., and reported a barometer reading of 29.66 inches and wind southwest 22 m. p. h. The steamship *Potomac* passed near the hurricane center on the 25th about 15 miles west of Abaco Island and reported a barometer reading of 27.30 inches (uncorrected). At Nassau the lowest pressure was 27.64 inches (unofficial) between 8 p. m. and midnight of the same date. The next report received from near the center was 28.09 inches on the steamship *Bessemer* in latitude 25° N., longitude 80′ W., at 8 a. m. of the 28th. The center passed over Long Key, the barometer falling to 28.18 inches at 9:30 a. m. of the 28th. The lowest pressure at Miami was 29.41 inches at 12:30 p. m. and at Key West 29.21 inches at 3:30 p. m. of the 28th. At Everglades, Fla., it was 28.95 inches at 5 p. m. and at Boca Grande 29.18 inches at 1 a. m. of the 29th. There were no reporting vessels near the center as it moved northwestward over the Gulf of Mexico, but apparently there was a slight decrease in the intensity of the hurricane before it passed inland near Panama City, west of Apalachicola, Fla. The lowest barometer reading at Panama City was 28.80 inches at midnight of the 30th. Apalachicola reported a minimum of 29.06 inches at midnight and Pensacola 29.19 inches at 2:40 p. m. There were in reality two minima at Apalachicola, the first, 29.23 inches, occurring at 3:30 a. m. of the 30th, while the hurricane center was still advancing toward the northwest. As the center continued to move in that direction for several hours thereafter, the barometer at Apalachicola rose slowly until 10 a. m., when it reached 29.39 inches. Shortly thereafter the hurricane recurved sharply toward the northeast and its center passed closer to Apalachicola than previously, resulting in the lowest pressure at midnight. The storm decreased very slowly in intensity as it passed over northwestern Florida and southern Georgia, Thomasville, Ga., reporting a pressure of 29.12 inches at 8 a. m. of October 1. After the 1st there was very little change in intensity until it reached the lower St. Lawrence Valley during the 4th, the nearest station to the center at each observation reporting between 29.30 and 29.36 inches.

The following maximum wind velocities were reported during the progress of the storm: Miami, 56 E. on September 28; Key West, 66 W., 28th; Fort Myers, 59 NE., 28th; Tampa, 33 E., 29th; Apalachicola, 59 S., 30th; Pensacola, 70 NE., 30th; and Jacksonville, 61 SW., October 1. No accurate information has been received regarding the force of wind in the Bahamas region, but it must have exceeded 100 m. p. h. near the hurricane center. The estimated velocity at Key Largo was (during gusts) about 150 m. p. h. There was a 10-minute lull as the hurricane center passed over this key. This hurricane was more severe than the 1926 hurricane at Key Largo. At Everglades the estimated velocity was 90–100 m. p. h. No estimate has been made of the maximum wind velocity at Panama City, where the center of the hurricane passed inland.

LOSS OF LIFE AND PROPERTY DAMAGE

The only report yet received relative to the hurricane in the Bahamas is the following Associated Press report, dated September 28:

> Severest hurricane struck Nassau from west 1:30 p. m., Wednesday (September 25), preceded by 24-hour gale from west in early stages. Rose very high, flooding road and carrying away sea wall and houses. After seven hours' blow from west and southwest the center was over Nassau. Lull four hours. Resumed midnight, blowing harder than before from the southeast and east. Damage done. Continued all Thursday (26th). Barometer at height of storm 27.64, abated Friday (27th). Still strong winds blowing. Damage to private property enormous. Few houses escaped, many unroofed, especially in colored quarter. Stores, churches, and shipping affected very severely. Mail steamer *Princess Montagu* blown out of harbor and stranded on Tony Rock. Rescued passengers and crew to-day. Mail vessel *Ena K.* safe in harbor. Many lives lost and casualties numerous. Impossible to estimate yet. No news from "out" islands. Feared some suffered severely. No communication yet.

The steamship *Wisconsin Bridge* went aground during the hurricane near Hole-in-the-wall Light on the southeastern tip of Abaco Island, and the tanker *Potomac* broke in two on Andros Island. With the exception of the fishing schooner *Mercia Montgomery*, which sailed from Apalachicola on September 18 carrying a crew of eight men, and was never heard from again, no other marine disasters of consequence have been reported.

The loss of life in Florida due to the storm was confined to a negro woman at Marathon, a negro child near Wewahitchka, and a man who lived near the beach at Panama City, who, although warned, refused to go to a place of safety.

Property damage was quite small in Florida. No damage of consequence was done on the southeast coast north of the keys, except at Fort Lauderdale, where a tornado (see account on p. 420, this review) that developed (probably as a waterspout?) over the ocean moved northwestward across the city and did approximately $100,000 damage. Tornadoes were also reported at Miami, Stuart, and Boca Ratone, but with no serious damage. While tornadoes in connection with tropical cyclones are of rare occurrence, it is noteworthy that the tornadoes referred to occurred in the right rear quarter of the tropical cyclone, as is usually the case when they occur

in connection with extratropical cyclones, although the Florida tornadoes occurred to the northeast of the cyclone center and those accompanying extratropical cyclones usually occur southeast of the center. In both cases the tornadoes move parallel to the path of the cyclones.

The greatest damage in the Florida Keys seems to have taken place on the northward side of the center—the upper Matecombe Key, the southern portion of Key Largo, and the Cape Sable and Ten Thousand Island areas. On the mainland south of Florida City, about 12 miles of the railway roadbed will have to be replaced. The damage at Key West was confined to the swamping of small fishing boats in the upper harbor, and temporary interruption of lighting and telephone service. A few thousand dollars will cover the loss.

While the wind attained a velocity of about 100 m. p. h. at Everglades and about 75 m. p. h. at Punta Rassa, very little damage has been reported from the southwest Florida coast. However, in Lee county there was an estimated damage of 20 to 30 per cent to oranges and 50 per cent damage to grapefruit. There was no damage of consequence north of Punta Rassa to and beyond Cedar Keys. In the vicinity of Apalachicola preventable damage due to the storm was comparatively small, but there was considerable damage to property that could not be well protected. The greatest damage occurred when high tides and heavy seas carried away practically every wharf along the water front and damaged all of the fish and oyster houses and canning plants. Some stock in stores in the lower sections was damaged by high water. The high tide and heavy seas did considerable damage to the new Gulf Coast Highway west of Apalachicola. Damage to the business and residential sections was of a minor nature although widespread.

Although the hurricane center passed inland at Panama City, the damage reported was remarkably small for a storm of this character. All wharves and several fish houses were destroyed in the Panama City area and the total monetary damage is estimated at between $100,000 and $150,000. At intermediate places between Panama City and Pensacola the damage was small. Satsuma orange groves and pine trees that had been turpentined in and near the path of the hurricane center suffered considerably. At Pensacola the damage was very small, the total being estimated at about $60,000.

THE SEPTEMBER 28, 1929, TORNADO IN FORT LAUDERDALE, FLA.[1]

By GEORGE B. HILLS

Beginning with the afternoon of the 27th of September, a hurricane, which was then nearing the Florida coast, evidenced itself through generally increasing winds and falling barometer. By 4 p. m. of the 28th the wind was blowing from a point south of east at a probable consistent velocity approximating 60 miles per hour and with gusts of greater velocity, temporary decreases, and continuous rain of varying intensity.

At about 4.40 p. m. I was in the back of my mother's house and I noticed that it was suddenly becoming very dark. Within probably two or three minutes the light was so poor that the reading of a newspaper in an inside room would have been difficult. The darkness was accompanied by a rapid and almost complete cessation of all wind.

I called my mother and went with her out onto a screened back porch, which afforded a relatively open view to the southeast, the south, and the southwest. (Her home is located east and slightly south of the main business section of the city.) I immediately saw a low cloud mass in the southeast, black with a golden or yellowish cast, which was approaching rapidly in a northwesterly direction. Within probably a few seconds it had approached to within approximately 600 feet of us and by that time its roar might be compared to the noise of several freight trains being slammed about close at hand. At that point the entire side and roof of a house flew up into the air at least 100 to 125 feet in height and then broke up into small pieces; other débris filled the air, and in a few seconds more the storm had passed on to the northwest and out of sight. Excepting that the flying débris was apparently moving in all directions, no rotating movement was observed. The heavy rains and poor light would have made any such observations difficult. The light quickly returned to normal with the passing of the disturbance.

Later investigations indicated that the disturbance had struck and moved along a path approximately three-quarters of a mile in length, beginning at the outer fringe of the residential section southeast of the business center of the city and moving northwesterly across the business center and through a negro section to the northwest.

The path of the disturbance varied from approximately 150 to 300 feet in width, and within its path it damaged or completely wrecked the frame houses, garages, trees, and other obstacles that it encountered. At the stormward side of the business section of the city it struck the exposed rear of a 4-story reinforced concrete and tile hotel from which it ripped the greater portion of the flat roof and the parapet walls above the top floor level. I saw two pieces of débris which I would judge weighed from 100 to 125 pounds, and which were identified as having come from the hotel structure, lying from 300 to 500 feet farther along the storm path.

Across the street from the hotel the storm struck fairly against a 10-story reinforced concrete office building, where the damage was limited to the breaking out of the large majority of glass windows on the east or stormward side. Apparently rising up over the building, the storm again struck the ground a few hundred feet beyond, completely blowing away all excepting the floor of the Railway Express Co. office and loading platform alongside the Florida East Coast Railway tracks. Two trunks and a dog belonging to a friend of mine, which were in the express company office at the time, had not been located the following day.

Continuing for perhaps a quarter of a mile before it apparently rose and disappeared, the storm destroyed most of a 2-story store building above the level of the second floor, and seriously damaged or destroyed a large storage warehouse and lumber yard, mill-working establishment, and several lightly built negro houses.

The entire damage along the path of the storm probably occurred within a minute's time and represented the only damage incurred in the city during the entire period of the hurricane.

[1] Scattered evidence has come to hand at various times that seems to indicate the occurrence of tornadic storms within well developed tropical cyclones. The editor is glad, therefore, to be able to present first-hand evidence of the occurrence of a tornado within a fully developed tropical cyclone. The tornado did not have the destructive violence that is associated with storms of like character in the interior of the continent, and its direction of movement, although contrary to that of most tornadoes, was in the same direction as that of the tropical cyclone.—EDITOR.

The outer limit of the tornado's path was sharply defined. A typical example was found in the instance of a house which we own, the corner of which was located 18 feet from the corner of a similarly constructed adjoining house. Our house was completely undamaged, while the adjacent house was completely destroyed.

Another example was found in the instance of a lightly built cottage with a slightly supported open porch, located immediately across the street from the lumber yard and mill-working establishment referred to above. While the latter was very badly damaged, the flimsy cottage across the street was not harmed in any way.

The captain of a large dredge anchored at Port Everglades, a few miles southeast of Fort Lauderdale, advised me that the tornado in coming in from the ocean passed between his dredge and a large barge anchored some 400 feet to the north without striking either. He advised me that he saw no evidence of a waterspout in connection with the tornado.

Mr. E. A. Pynchon, a civil engineer and shipyard owner of Fort Lauderdale, was watching a recording barometer in Flippen's hardware store when the storm center passed within some 300 or 400 feet of that building. He states that the needle dropped abruptly nine points, quivered at the low point for a few moments, and then rose abruptly to the original reading. The graph record indicated a vertical line drop and rise of five points.

The passing of the tornado apparently marked the peak and end of the hurricane disturbance at Fort Lauderdale. Within 30 minutes after its passing a decrease in the intensity of the hurricane winds was definitely noticeable, and within two hours the wind velocity was probably down to 30 miles an hour or less. Thunder and lightning had developed in the east by that time, and the storm decreased continuously thereafter. The recording barometer indicated a steadily increasing pressure after the passage of the tornado.

ADDITIONAL EVIDENCE

Following is an excerpt from the report of the cooperative observer at Fort Lauderdale:

I did not see the tornado, but heard the noise, but as the hurricane was causing so much noise did not notice that of the tornado. My daughters were sitting in the bedroom on northeast side of the house, and came running to the porch and wanted to known what the air was filled with that was going past on the north side of my house. Some who saw the tornado speak of it as a "ball of fire." The tornado went through the city bouncing like a ball; places in its path would not be touched, then it would strike some building and tear it into pieces.

THE STATUS OF CLIMATOLOGY OF THE AGES

By MARSDEN MANSON

Physical facts are the language of Nature and every expression uttered by her is worthy of our most attentive consideration—MAURY.

When the climatologist turns from his volumes of observed data to the climatic records made by natural processes he enters one of the most interesting and important fields of his science.

He can not climb a mountain in any latitude to an altitude at which glaciers yet rest without finding evidences of their retreat and of the corresponding advance of forest growth. It makes no difference where these observations be made, whether in reaching the feeble remnants of glaciers in the Sierra Nevadas, the Alps, the Himalayas, or upon Ruenzori, Chimborazo, the greater glaciers of Alaska or Patagonia, or the vast ice sheets in polar latitudes, the records are the same—*continuous retreat*. Possibly fluctuating slightly, but everywhere the integrals of successive retreats are far greater than those of advances.

Retracing his steps he can observe what may have escaped his notice at first, that the glaciers once extended to lower and lower slopes, until, in temperate latitudes. they reached the bases of the mountains and left morainic soils on which grapes, olives, and oranges now flourish, or in tropical and equatorial latitudes the evidence of glaciation are buried in dense forests only a few thousand feet above sea level.

Should his studies be broadly conducted he can trace these evidences of deglaciation across a continent and to the north of these limits vast glacial lake beds now producing abundant crops of wheat and oats.

In this he enters the enticing fields of paleo-climatology. In these he is called upon by the geologist to explain the evidences of a series of alternations between severe and destructive glaciation and the geniality of the insolation in latitude, or the warm and cold interglacial epochs of Pleistocene glaciation; and the transition of the last of these warm epochs into existing conditions and the principles of physics involved in this transition.

All of his observations establish a distribution of temperatures entirely different from those of to-day, and contradicting every principle of modern climatology. He will be forced to the conclusion that the retreat he has so clearly traced, and observed as yet in progress, reveals the closing chapters of a distinct transition from the conditions and control of paleo-climates into those of modern climates.

Neither branch of his science, as at present taught, gives in any particular the reasons for this change or transition between the two distinctly different and contradictory climatic records, nor why, when, where, and how modern climates began and paleo-climates ended, or of the causes of the stages in this transition. Nor again to the naturally suggested question, to what conditions do the progress and control, evidently inaugurated at some indefinable period and in some undetermined regions, now lead? He is irresistably led into the interpretation of these enticing and unmistakable records which are contrary to the distributions of modern climates, contradict them by glaciations in all latitudes which could not occur under the accepted constancy of direct solar radiation, nor do they yield to any assumption of variation in solar radiation, for they are utterly incongruous to such direct control as solar energy can impose on a planetary surface inclosed in air and having water within its control; contradicts them by the glaciations of temperate latitudes extending into polar latitudes, while tropical latitudes at or near sea level continued to enjoy the geniality of their insolation; contradicts them by the most severe and destructive glaciation recorded at sea level in tropical latitudes during Permo-Carboniferous time, coincident with subpolar and polar geniality with no sign of glaciation. These considerations lead us into paleo-climatology and into the period or periods and the latitude or latitudes in which the

transitions between the two great divisions, modern and paleo-climatology, occurred and into the tendency of climatic advances of the present era.

Returning to our climatologist's observations on his ascent from lower levels in middle or in tropical latitudes, on either his ascent to or descent from the yet existing glacier levels, he will note that the various species of trees are ranged between definable limits, whether coniferous or deciduous they have definite limits which are slightly higher on south exposures. Each species has its limits, but each is pushing its upper limits into the lower limits of the next species above, until, as he reaches the timber line the hardiest conifers, aspens, and willows are pushing their dwarfed and struggling forerunners toward the retreating glacier level. These records are the same in whatever latitude the glacier limits are approached.

These plainly legible records establish the fact that one of the most characteristic and distinguishing features of present climatic distribution and control compared with geological climates is deglaciation, that whatever may have been the conditions and control which permitted the last, or Pleistocene glaciations, to be laid down, these conditions and control no longer prevail in any latitude, and have been completely reversed, so as to cause progressive deglaciation and amelioration in proportion to insolation in latitude and altitude to alternately and then permanently take the place of refrigerations and glaciations.

In other words, the cumulative effects of insolation under present climatic conditions are still removing refrigeration and glaciation and extending in their stead more genial conditions.

The present retreat of glaciation and the advance of vegetation over the deglaciated areas establish the actual progressiveness of geniality over the entire globe. This advance is not in harmony with the conclusion of Abbe:

> It is evident that our planet, considered as a whole and on the average of many years, loses all the heat which it receives from the sun, but all the details of this process have not been worked out.[1]

This conclusion, however, held and supported by the interpretations of meteorological observations, can not stand in the face of the direct evidence naturally recorded throughout the world and just reviewed. It must, therefore, be abandoned and replaced by the conclusion that present climatic conditions are not static nor in equilibrium but are advancing toward a condition advantageous to human life, and that the climatologist must consider his science as dealing with progressive conditions.

In the practical work of the meteorologist, or the forecasting of local weather changes, the gradual advances herein pointed out are of no use. But it must be realized that the present climates are the results of agencies yet progressing in their results, and are essential to a clear understanding of the facts and the basic principles of physics involved in the genesis and advance of the climates with which he has to deal.

It is well known through the researches of many investigators that, in general, water vapor is transparent to incoming short-wave radiation but opaque to outgoing long-wave radiation.

Recent investigations by Simpson and others seem to prove that the absorption of solar heat just balances terrestrial radiation of heat. In all of these investigations, however, instrumental measures and the deductions therefrom are not of so refined a character as to close the door to the possibility which may be a certainty, that there is a small residual of incoming in excess of outgoing radiation.

[1] Am. Journal of Science, Vol. XLIII, p. 364.

This process was manifestly established as Pleistocene glaciation began its final retreat, and within certain reasonable limits is cumulative; it is yet active; this activity is being recorded by retreating glaciation and advancing geniality, as above pointed out.

This advance in certain local and minor instances may have been fluctuating, but the major facts are indisputable and convincing.

We must therefore adjust or modify the principles of climatology to meet the requirements which the naturally recorded phenomena plainly establish and known principles of physics account for.

The phenomena with which climatology has to deal are therefore not static nor in equilibrium, but are advancing toward a condition in which the moss of the tundra will give way to rye and wheat and "ice covered polar wastes will be useful to the human race."

There are therefore two vital and important inquiries of great import in the status of climatology.

(1) From what conditions and control did the changes from geologic climates come?

(2) To what condition do the changes but recently inaugurated tend?

Until climatologists are able to grasp the meaning of the actual records confronting them they have a limited conception of the scope of their science and of its importance to the ultimate future of the human race.

There are two manifest fallacies which must be discarded before climatology can rest upon an assured basis, particularly in the division of paleo-climatology.

Intensive research by geologists into the climates of the past has revealed the fact that the present distribution and control of climates are distinctly different from those of the past.

These great differences have necessitated the division of climatology into modern and paleo-climatology. This distinction sets apart the climates of to-day from those of the past ages only by scientific nomenclature, for when it is asked how, when, where, and why did the changes or transitions from one to the other take place, neither branch of the science gives any definite answer to questions which any high-school student might be expected to ask.

Again, since curiosity is the mother of research, he might be tempted to ask, Where do the conditions which this transition inaugurated lead?

The writer can not find in any text or manual on climatology satisfactory answers to these questions.

The status of climatology as a science is therefore indefinite and unsatisfactory as to how the genesis of present climates was brought about and as to what conditions they tend.

One of the most direct references to this transition is found in Geikie's Text Book of Geology where, after reviewing the great fluctuation of climates in the Pleistocene ice age, he says:

> The long succession of Pleistocene ages shaded without abrupt changes of any kind into what is termed "The human or present period."[2]

However lacking in abruptness this shading or transition may have been, it is not lacking in its reality and in the significance of its results, as completing the most momentous transitions of climatic, geologic, and biologic history, accomplished through a succession of interrupted transitions or interglacial warm and cold epochs, and culminating in a final transition in each of the great zonal glaciations. These transitions were inaugurated "in the

[2] Vol. II, p. 1347.

midst" of climatic, geologic, and biologic history by a glaciation more severe and more incongruous than any recorded in the crust of the earth, for in Permo Carboniferous glaciation tropical latitudes were severely and destructively glaciated down to sea level, and subpolar and polar latitudes remained genial, thus reversing every principle of solar climatic distribution and control and offering "a plexus of problems of unparalleled difficulty."[3] The final transition was accomplished as Pleistocene glaciation merged in temperate and polar latitudes into existing climatic distributions.

Wide range has been given to the scientific imagination to develop solutions based upon hypotheses, assumptions and calculations resting upon assumed data, all resulting in unsatisfactory solutions of the climatic problems presented by the researches of geologists.

The last of these is Wegener's theory of floating continents. This is referred to by Dr. G. C. Simpson as follows:[4]

> There has recently been a considerable interest taken in problems connected with past climates. Wegener's revolutionary theory of the movements of the continents, associated with wanderings of the polar axis, has met with serious and strenuous opposition. One of the most important of the appeals of Wegener's theory is that it gives an explanation of the great changes of climate which geological evidence indicates to have taken place in many parts of the world.[5]
>
> This has been a direct challenge to opponents of the theory to produce explanations of these climatic changes on more conservative lines. Variations of solar radiation is the most obvious solution, but there are many patent objections to such an explanation and there seems a reluctance to postulate any but small changes in solar radiation. At any rate this is not a popular solution.
>
> Geologists look with much more favor on theories which depend only on changes in the physical status of the earth's surface; changes in the relative extent of sea and land, changes in ocean currents and changes in elevation, although the latter can only work in the direction of reducing surface temperatures.
>
> It seems to me to be the opinion of many geologists and not a few meteorologists that there is unlimited scope for the control of climate in the readjustment of land masses and the introduction of new ocean currents similar to the Gulf Stream.[6]

The "revolutionary" theory of Wegener does not appear to meet any of the rigid requirements of geologic climates as established by geologists; the crucial objections are:

(1) The floating of the continents upon a slip joint or surface discretely postulated beyond possible examination.

(2) The repeated alternation in climates during Pleistocene glaciation from severe and destructive glaciation to the geniality due the insolation in latitude calls for the floating of continental areas in both hemispheres from polar latitudes into temperate latitudes to be deglaciated and back again to polar latitudes to be reglaciated.

The same back-and-forth floatation between tropical and polar latitudes would be necessary to account for corresponding alternations in climate during Permo-Carboniferous glaciation and the floating would have to be far greater in latitude.

Moreover, the whole change is based on the unproved assumption of solar control of geologic climates, which assumption has proved unsatisfactory in all cases.

The hypothesis can not be allowed to stand as even one of the possible causes of climatic change.

[3] Chamberlin and Salisbury Geology, Vol. II, p. 655.
[4] In Past Climates, Quart. Journal Royal Mt. Soc. July 1927, pp. 213-230.
[5] W. Köppen and A. Wegener, der Klimate der Geologishen Vorzeit, Berlin, 1924.
[6] Seward Phil. Transactions B 215, 1926, p. 161, Brooks Climates through the Ages. London, 1926.

PSYCHROMETRIC OBSERVATIONS

By Capt. M. COYECQUE, Master Steamship *Basse Terre*

Psychrometric observations have been made during the voyage from Bordeaux, France, to Pointe-á-Pitre, Guadaloupe (September 11–26, 1929), with the object of realizing when there was any opportunity and advantage to open the hatchways for ventilating the cargo outside of the regular air current obtained by the ship's ventilators. The apparatus used was the regular Richard psychrometer, placed in a sheltered position, exposed to the wind and moved according to the sun's movement and the ship's course.

The absolute humidity in grams per cubic meter has been figured from the Smithsonian tables and the specific humidity in grams per kilogram calculated by the formula

$$H_s \frac{623f}{p.-0.377f}$$

f being the absolute humidity or vapor tension in mm. and p. the pressure in millimeters. The observations have shown along the course indicated by ship's position the following results:

In the Gulf of Biscaye with fair weather, H_s was only 12.3 grams with a temperature of 20°.5 C. It decreased continuously between Spanish coast and Azores, showing a minimum of 11.3 grams in latitude 37 and longitude 31—in the southeast sector of a high-pressure zone slowly moving east-southeastward (wind NE. 3). After that day H_s increased slowly until latitude 31 was reached. The ship then passed into tropical air from southeast, after a heavy thunderstorm moving northwestward. The specific humidity, which had increased 3 grams in three days, made a jump of 3 grams in a few hours and maintained its degree afterwards.

From 17 grams it slowly reached 21 grams on the 24th in latitude 21 with appearance of cyclonic conditions in the region. As the weather conditions improved and showed less turbulency, H_s fell down to 19 grams, and increased again to 21.9 grams close to the Guadaloupe coast, with squally weather and temperature 27°.5 C. As a rule, morning observations made about 8 a. m., local time, showed higher specific humidity than p. m. observations. Evening observations were generally intermediate and close to p. m. data.

As a conclusion, the driest part of the voyage was the period southwestward of the Azores in the polar air of the moving HIGH. All the way farther south the air was richer in moisture than the air from Bordeaux, where cargo had been loaded.

THE FRUIT-FROST WORK OF THE WEATHER BUREAU IN THE UPPER SAN JOAQUIN VALLEY

By CHARLES C. ALLEN

[Weather Bureau Office, San Francisco, Calif.]

It is common knowledge that in the more important fruit-growing districts of California orchard heating for protection against frost damage is practiced more or less extensively. This is particularly true in the principal citrus producing sections. In recent years considerable interest has been aroused in the deciduous fruit sections in northern California, the interest usually arising in individual localities after a season of general frost damage followed by high prices. After each such season in late years there have been spasmodic preparations for heating of orchards, so that in the course of time most fruit growers have become acquainted in some measure with the theory and practice of orchard heating.

Inasmuch as orchard heating on many ranches involves measures which may be described as extraordinary—that is, altogether outside of the normal routine of the ranch work—the desirability of *preparedness* against frost was immediately recognized. The grower was quick to realize that dependable warnings of frost were essential to successful orchard heating on a large scale, and accordingly, at an early stage in the development of orchard heating in the deciduous-fruit sections of northern California, a plan of cooperation was worked out between the Weather Bureau and the county agents of the United States Department of Agriculture Extension Service for the issuance of frost warnings with widespread dissemination. By this plan, which was made applicable to any county on request of the extension service, and which has now been in operation for several years, the county agent arranges for advices of local weather conditions to be telegraphed to the district forecast center of the Weather Bureau at San Francisco each afternoon during the danger period. These local indications are given consideration by the district forecaster, who then prepares a frost warning which is telegraphed to the county agent for distribution. The warnings are also broadcast by several radiophone stations in the vicinity of San Francisco.

It was the experience of several of the county agents that as need for the forecasts developed over an ever-widening territory, attention to the details of the work and to local distribution made demands for their time such that the work became a real burden; in particular, local distribution of the forecasts required several hours of night work. Furthermore, it was soon found that additional refinement or localization of the general forecasts was desirable, work which would require the services of a professional meteorologist. For these reasons another plan was tried, first in Stanislaus County in 1926, by which a meteorologist of the Weather Bureau fruit-frost service would be assigned to the county during the period February 16–April 30 of each year to handle all details of the frost-warning service. This plan of operation was followed in Stanislaus County from that year to the present, and in 1929 the service was extended to two adjoining counties, San Joaquin and Merced, when it was found that this could conveniently be done. The Weather Bureau provides the fruit-frost service in these counties somewhat after the plan followed by the United States Department of Agriculture Extension Service in cooperating with the counties; that is, the Weather Bureau pays the salary of the meteorologist, provides the equipment, and bears the considerable expense of telegraphic communications outside the counties, while the counties pay current operating expenses. Credit for securing the fruit-frost service for these counties is due mainly to the enterprise of the county agents now officiating—Messrs. Jungerman, Patton, and Quail, who secured from the boards of supervisors the necessary appropriations from county funds.

The benefits offered by this plan are, briefly, a localized frost-warning service with adequate distribution among the growers; an accurate and impartial temperature survey of the chief fruit-growing areas; and a personal advisory service for the growers on orchard-heating problems. As to its ultimate value to the community, it can be said that wherever the importance of fruit growing, with its attendant problem of orchard heating, has in the first instance warranted the fruit-frost service, the service provided has ordinarily proved so helpful to the growers that they request its continuance from year to year.

By some strange irony it happened that during the first three years of the service in Stanislaus County not one really damaging frost occurred, so that it became a standing jest among the growers that the county was paying the meteorologist Chinese fashion to prevent frost. While absence of killing frosts afforded much pleasure to the farmer, it proved no blessing to the fruit-frost service. for there was not the essential accumulation of data on damaging frosts for study. As events later proved, the work of forecasting for this new territory was made very difficult by the lack of such records for study and comparison. Considering, then, that during the first three years of the service there was apparently no need for it, it speaks well for the foresight of the county agents that not only was the service continued for the fourth consecutive year in Stanislaus County, but was extended to San Joaquin and Merced Counties as well. Their action was amply justified, for the spring of 1929 was one of the coldest on record, with a series of damaging frosts that took tremendous toll of nearly all varieties of fruit in the district.

It can be said with emphasis that the 1929 season was a stringent test for the fruit-frost service. The occurrence of the severest season in many years at the time when forecasts were made for new territory provided a combination of circumstances as unfavorable as ever likely to be encountered. It is well known to professional meteorologists that the method of forecasting minimum temperatures which has been found most successful in California utilizes an algebraic formula devised by F. D. Young for an original estimate which is modified by reference to prevailing weather conditions. Certain constants required by this formula are calculated from past records: hence it will readily be recognized that use of the formula without sufficient records of past frosts to calculate such constants was attended by no little uncertainty. Moreover, it was found that for a region without striking topographic differences the variations of minimum temperatures on a given morning were astounding. It was also observed, owing no doubt to the instability of the weather during the spring, that nocturnal winds or cloudiness could not invariably be forecast from the evening weather map; hence frosts did not always materialize when conditions seemed favorable. The conclusion inevitably follows, therefore, that while forecasting of the minimum temperatures in

this section will probably never achieve the accuracy attained in other sections, yet any failure is usually on the side of safety, and ample warning of frosts can be given. During the 1929 season no damaging frosts occurred without issuance of warnings to the growers sufficient to enable them to make needful preparations for the night. This in itself should be considered a demonstration of the utility and feasibility of a frost-warning service, and it is not too much to say that the growers have profited from the service in the past to the extent that it may be considered indispensable in the future from their point of view.

WEATHER FORECASTS IN RELATION TO THE MARKETING OF CITRUS FRUITS

By FLOYD D. YOUNG

[Weather Bureau office, Pomona, Calif.

Nearly all agricultural crops are subject to hazards of weather throughout their growing period, but the successful growing and marketing of citrus fruits depends to a large degree on the behavior of the weather throughout the entire year. Severe winter frosts sometimes destroy the greater part of the crop on the trees, and millions of dollars have been spent for frost protective devices. If unduly high day temperatures or low night temperatures occur within a day or two following the fumigation of orange trees for insect pests, much of the fruit is likely to fall to the ground, and the foliage often shows considerable injury. Unseasonably high temperatures in June, soon after the end of the blossoming period, often cause a heavy drop of small green fruits. Hot, dry, desert winds in some districts in California damage fruit and foliage nearly every year. Long continued periods of rain or dense fog sometimes stop orange-picking operations for days, or even weeks, and cause a heavy decay of fruits on the trees.

The Weather Bureau has been aiding the growers and packers of citrus fruits to ameliorate these difficulties as much as possible through forecasts of periods of adverse weather. Only recently, however, has much attention been paid to issuing forecasts to aid in meeting marketing problems caused by weather conditions.

It has long been recognized that lemon sales depend to a very great extent on summer temperatures in the districts where fruit is sold, and in recent years, since the consumption of orange juice has increased so materially, the sale of oranges has been similarly affected. There is a steady demand for lemons throughout the year for culinary and general purposes, but the use of lemons for beverage purposes takes place largely during the hot summer months. More than 50 per cent of the total yearly lemon sales are made during the period from May to August, inclusive.

Speculators buy and store lemons in the eastern marketing centers during the late spring to care for normal consumption during the early summer, but unusually high temperatures or long continued hot weather soon exhausts the supply, resulting in a shortage of fruit and abnormally high prices. There is practically always an adequate supply of lemons in storage at the packing houses in California, but it requires about 10 days for a car of fruit to reach the eastern markets, and individual periods of hot weather usually do not last more than a week. Forecasts of higher than normal summer temperatures in eastern markets made two or three days in advance permit the shipment of additional supplies of fruit from California to reach the markets before an acute shortage of lemons has developed, make possible the sale of a larger quantity of fruit, and maintain a more reasonable price to the consumer.

California had an unusually large crop of lemons to market during the summer of 1928. During the early part of June continued cool weather made it very difficult to move the crop in satisfactory volume and obtain fair prices. On June 27 the San Francisco forecaster advised the marketing agency in Los Angeles that temperatures above the seasonal normal were to be expected east of Mississippi River within a few days. On that date about 700 cars of lemons were on track in the East or en route. The market was declining, and it had been decided to reduce shipments from California until the market showed signs of improvement. On receipt of the forecast, shipments were continued without reduction. The effect of the hot wave was reflected almost immediately in the lemon market. On July 5, 184 cars of lemons were sold by the California Fruit Growers' Exchange, constituting the largest sales on any one day in the history of that organization. The price per box f. o. b. California averaged for all these cars $4.73, the highest car-lot price since 1921, with the exception of 1923, when the price average was on only 28 carloads. The net return on these 184 cars of fruit was $315,000. If shipments had been curtailed, as had been planned before the receipt of the forecast, less fruit would have been available for sale and the price to the consumer would have been much higher.

During the winter months cold waves or unusually heavy falls of snow in the eastern markets not only interfere with the movement of citrus fruits from California by rail, but also materially reduce the consumption of fruit. During periods of unusually cold weather in the winter of 1928–29 considerable fruit was frozen in the cars en route to market, and some important markets were closed entirely, due to heavy snow. No citrus fruit was unloaded in Chicago over a period of several days during one of the severest cold spells.

Forecasts of these cold waves in eastern territory enable the marketing agencies to hold entire trainloads of fruit in the warmer southern territory and at railroad division points, where the cars are kept in heated sheds until temperatures have moderated. The picking and packing of fruit in California is discontinued until the market has had time to recover from the demoralization caused by the low temperatures and heavy snow.

The writer believes that special forecasts of the type that have been described will prove to be of increasing value to many industries in the adjustment of marketing problems caused by weather conditions. This is a field for service of great practical value, and a field which is capable of much greater development, now that facilities for making more accurate forecasts for periods of several days are becoming available.

CALIFORNIA SNOW SURVEYS[1]

By HARLOWE M. STAFFORD, Hydraulic Engineer, Division of Water Rights, State Department of Public Works

It was only in the last day or so that I was advised that a statement was desired at this meeting from our State department concerning the proposed entry of the State into the work of the Sierra snow survey. For this reason and also because of the fact that the project is still in very preliminary stages, my remarks will be somewhat brief and sketchy. When the work is under way and opportunity is afforded for study and analysis, we shall be pleased to offer you something which I am sure will be much more profitable than my present statement.

The history of California snow surveys, so far as the State itself is concerned, goes back to about 1917, when Major Norboe, then chief assistant State engineer, arranged for an informal cooperation with Nevada for surveys at a few stations. This cooperative effort was continued until about 1923, when California withdrew because further funds for this work were not then available. During this period the cooperative snow surveys were conducted chiefly in the Yuba, Tahoe, Truckee, and Carson Basins, at summit stations of the American and Mokelumne, and, I believe, in the upper Walker Basins.

Major Norboe was in very close touch with Doctor Church, of Nevada, and the methods employed in the surveys were largely those devloped by Doctor Church in the Nevada work.

I believe Doctor Church has appeared before this society many times and that you are probably thoroughly familiar with his work and international reputation in snow surveying. This brief reference should therefore be sufficient.

About two years ago there appeared to be a growing demand that California should again reenter the snow-survey work, and the California Development Association, through its California Economic Research Council, adopted the furtherance of this idea as one of its projects. Request was made of Mr. Conkling, chief of the State division of water rights and a member of the research council, that his department conduct an investigation to determine the extent of present snow-survey work on the part of power companies, irrigation districts, and others and to sound out the general desirability and demand for any extensive work of this nature by the State. Questionnaires were sent to a number of these agencies, and the speaker made contact with many and obtained reports of the data now being obtained, their methods, and the degree to which dependable forecasts were possible from the results of the surveys. A conference was also held at Reno with Doctor Church and Professor Boardman, chairman of Nevada's cooperative snow survey committee, and the possibilities of the California work were discussed.

As a result of its investigation the division of water rights reported on January 14, 1929, to a special conference of the research council members and representatives of those public and private agencies directly interested, that nearly every agency was strongly in favor of the States undertaking this work and that the results that had so far been obtained by Nevada and the agencies in California would appear to justify such a step. Accordingly, action was taken to forward the proper legislation at the recent session of the legislature. I wish to read a portion of the letter sent by this conference to Mr. A. R. Heron, director State department of finance, and to Mr. B. B. Meek, director State department public works, as this sets forth clearly and briefly the purposes of this work and what it is hoped may be attained:

SPECIAL CONFERENCE ON SNOW-SURVEY PROJECT

SACRAMENTO, *January 14, 1929.*

Chairman C. L. Hill, of the natural resources committee, California Economic Research Council, called a special conference of the representatives of those public and private agencies most directly interested in the possible results of snow-survey investigations, in Sacramento on January 14. The object of the conference was to consider the various needs for such work, its importance and possibilities, and to present a unified statement or recommendation to the State departments involved or to the legislature.

Those in attendance included C. L. Hill, United States Forest Service (chairman): H. F. Ormsby, secretary California Economic Research Council; E. H. Bowie, United States Weather Bureau; William Durbrow, president Irrigation Districts Association of California; F. R. George, Pacific Gas & Electric Co.; Charles Mardel, Great Western Power Co.; C. A. Logan, State division of mines and mining, Harold Conkling, chief; and Harlowe Stafford, State division of water rights.

Results of the conference are summarized in the following letter and recommendations:

Copy of letter sent to Mr. B. B. Meek, director department of public works, and to Mr. A. R. Heron, director State department of finance.

"Some time ago the California Economic Research Council, pursuing its objective of improving our basic sources of useful economic information, agreed in a general statement, acted upon by its entire membership, that comprehensive state-wide records of snowfall and snow pack would be a most valuable and necessary extension, due to the increasing importance of forecasting the annual water crop from our high mountain watersheds.

"Accordingly, this council committee on natural resources was authorized to investigate the various practical needs, the present facilities available, and the possible direction and results of coordination and extension of this work. At the request of this committee your State division of water rights has collected information along these lines, summarized in a mimeographed report inclosed. (Copies of this report can be obtained from the State division of water rights.)

"On January 14 the chairman of this committee called a conference in Sacramento to review the situation and to recommend such action as would seem desirable by a representing group of those interests most directly affected. This included representatives of the two major power companies operating in the Sacramento and San Joaquin Valleys, the irrigation districts of the State, the United States Weather Bureau, the United States Forest Service, the State division of mines and mining, the State division of water rights, and the California Development Association.

"The information developed through this conference and previous investigation was, briefly, that the snow-survey work now done by the power utilities, irrigation districts, and other private interests, such as Professor Church, of the University of Nevada, has proven that reliable forecasts of run-off are possible on local watersheds. It is most desirable that these scattered private efforts be coordinated under State supervision, and they have expressed their willingness to cooperate. That in addition to standardizing and centralizing the information now privately collected, the State should extend the work to fill the gaps and obtain comprehensive annual records for at least the entire Sierra Nevada watershed.

"The benefits to be derived from an adequate system of state-wide snow surveys and water-run-off predictions are not confined to the immediate practical or local uses by power companies, irrigation districts, and municipal water companies in the administration of their projects. The broader necessity is for such information to guide the use of water from year to year over large areas, such as the entire length of the Sacramento River, where for example, an increased acreage of rice by upper water users means a diminished flow in the delta region and salt-water incursion if the summer flow is not ample. The same condition and necessity applies on the San Joaquin River, Kings River, etc. The power utilities and power projects in connection with irrigation also can use the information in a broader way to forecast the load demand for pumping in the areas they serve.

[1] Presented at the meeting of American Meteorological Society, Berkeley, Calif., June 21, 1929.

"In view of these facts, the conference assembled decided that immediate action was necessary, in order to start such work, and adopted the following recommendations, which are presented for approval by you, and by other agencies interested.

"'1. *Resolved*, That state-wide snow surveys for the purpose of predicting water run-off are desirable, and that the State should undertake the standardization and correlation of private work now under way.

"'2. *Resolved further*, That the State should extend these snow surveys to include an adequate record for the entire Sierra Nevada watershed, presumably through its present division of water resources.

"'3. *Resolved further*, That legislative authorization and appropriation of funds to permit the initiation of this work during the forthcoming biennium should be sought immediately.'

"In the interest of time, this conference group has had drafted a bill carrying a biennial appropriation of $40,000 for introduction before the close of the present session of the legislature. The estimate of cost was submitted at our request by the division of water rights.

"Realizing your knowledge of the water situation, we are presenting this matter for your consideration without the more detailed information which could be given, and would ask in behalf of the conference group your indorsement of the proposed legislation.

"Sincerely yours,

"(Signed) C. L. HILL,
"*Chairman Natural Resources Committee.*"

Copy of suggested legislation:

STATE-WIDE SNOW SURVEYS

"An act to provide for the making of snow surveys and the gathering and coorelation of information pertinent to an annual forecast of seasonal water crop and making an appropriation therefor.

"The people of the State of California do enact as follows:

"SECTION 1. The division of water rights of the department of public works is hereby authorized and instructed to make snow surveys and to gather and correlate information for the purpose of acquiring data necessary to an annual forecast of seasonal water crop and to do all or any of such work either independently or in cooperation with one or more persons, firms, associations, corporations, or other agencies, including county, State, and Federal agencies.

"SEC. 2. For the purpose of carrying out the provisions of this act the sum of forty thousand dollars ($40,000) is hereby appropriated out of any money in the State treasury not otherwise appropriated, and the State controller is hereby directed to draw warrants upon such sum from time to time upon requisitions of the division of water rights as approved by the department of finance, and the State treasurer is hereby directed to pay such warrants."

(Assembly bill 403, introduced by Assemblyman Crittenden on January 16.)

An appropriation of $30,000 for the California snow surveys was passed by the legislature and just signed by the governor within the last few days.

As to the program for the work, the letter which I have read outlines in general the scope. It entails a coordination, standardization, and centralization of the work and data now conducted and secured through scattered private effort, as well as considerable extension, to make the survey as complete as possible with the funds available.

In a voluminous report submitted in 1923 to the California State engineer by Doctor Church, an outline was given for a comprehensive snow survey of the Sierras, and, as far as present plans have been formulated, this outline will be used as a guide in developing the work. Also the survey methods developed by Doctor Church will be largely used. As I have said, I believe you are familiar with these methods. In briefest terms, the procedure comprehends the determination of the water content of the snow cover over properly selected snow courses in each basin or region by means of suitable sampling apparatus and, from the data obtained, the determination of the percentage relationship of the seasonal snow cover of that basin to its normal, under the assumption that such percentage is indicative of the coming seasonal run-off in the streams below.

Under the plan suggested the Sierras are divided into the northern, the central, and the southern quadrangles, and in each quadrangle the survey would cover the various basins by means of sufficient courses at crest, eastern and western outposts. In the northern quadrangle there would be the Upper Klamath, the Upper Sacramento, the McCloud, and the Pit Basins; in the central, the Feather-Honey Lake, Yuba-Truckee, American-Tahoe, Mokelumne-Carson, and Stanislaus-Tuolumne-Walker; in the southern, the Merced-Mono, San Joaquin-Upper Owens, Kings-Kern-Lower Owens, and Kaweah-Tule.

The investigation by the division showed that more or less extensive surveys are now being made annually in the South Yuba and Upper Mokelumne Basins by the Pacific Gas & Electric Co. at some 11 stations, totaling 17 snow courses; in the North and West Kings River and North San Joaquin Basins by the San Joaquin Light & Power Corporation at some 40 stations and courses; in the Upper San Joaquin Basin by the Southern California Edison Co.; from Cottonwood Basin, at the lower end of Owens Valley, to the Mono Summit above Long Valley by the Los Angeles Bureau of Water Supply; in the Bishop, Rush, Leevining, and Mill Creek Basins, in Mono and Inyo Counties, by the Southern Sierras Power Co.; in the Lake Almanor and Butt Valley watersheds by the Great Western Power Co.; in the North and Middle Yuba Basins by the Nevada Irrigation District; in the Merced Basin by the Merced Irrigation District; and in the various basins draining to Nevada which come, of course, under the State of Nevada Cooperative Snow Surveys.

In nearly every case the Church methods or some modification thereof are being employed. In some cases the data have been analyzed to determine actual estimates of run-off which have proved notably accurate, and in others the data are merely tabulated for comparative purposes, but no definite forecasts of run-off made.

One of the chief functions of the State snow survey will be the correlation of these individual efforts, and in all cases a great willingness and earnest desire to cooperate with the State has been expressed.

In the extension of the work to fill in the gaps and supplement the present surveys the problems are not simple. Where the snow-cover run-off relation is confined to the upper basins and high altitudes, the physical difficulties are of course considerable, but those attendant upon the interpretation of data and analysis are comparatively slight. When we come to the lower elevations, however, and attempt to forecast run-off at foothill and valley points, we enter the zone of early melting snow, precipitation, as rainfall, etc., and the difficulties increase. In the Sacramento Basin, as an exmple, the stream flow is derived largely from storage in the lava beds derived mostly from rainfall, with some melting snow. It goes without saying that the snow survey must be definitely tied in with the many precipitation stations of the United States Weather Bureau at the lower elevations if proper forecasts for the lower points are to be made. In each quadrangle it will also probably be necessary to establish supplementary precipitation and temperature stations. In addition, at certain key stations it may be advisable to establish facilities for observation of more complete meteorological data, such as humidity, pressure, temperature, wind direction and velocity, etc. In the conduct of the snow surveys the plan would call for one complete survey at all courses about April 1 of each year for the preparation of the main forecast bulletin as of

about that date. At slected stations and courses, however, the survey may be conducted monthly or at frequent intervals to furnish the data for supplementary forecasts prior and subsequent to the main forecast.

The task is rather large and must be approached cautiously. The establishment of new courses will take some time. The selection must of course be made in the winter when the snow is there and when the suitable location of shelter huts, etc., can only be made. Little more than reconnaissance can therefore be expected in the coming winter for the new stations. The following summer the shelter huts can be built and stocked and the courses carefully marked in preparation for the actual surveys the following winter. In the meantime, however, there is much that can be done in the way of securing standardization and distribution of equipment, organization of personnel, preparation of standard forms, arrangements for cooperation with existing surveys and standardization of them as to methods, reports, equipment, etc.

This may serve to give you some idea of the project and what lies before us. As I stated in the beginning, when the results of two or more years are behind us we may be able to bring to you, should you desire it, something of greater interest to a scientific body of this nature than the mere prospectus of a project.

NOTES, ABSTRACTS, AND REVIEWS

Origin of nor'westers.—During spring and summer Bengal is occasionally visited by a type of severe thunderstorms locally known as the *Kal-Baisakhi*, or the "fateful thing" of the month of *Baisakh* (April 15–May 15). These storms usually approach a station from the northwest and burst suddenly with great fury. The path of a nor'wester may vary in width from a few hundred feet to a mile, and the distance overrun seldom exceeds 50 miles. These storms are more frequent in the late afternoon, although they are known to occur also at other times of the day. A nor'wester is always associated with a thundershower, and the precursory signs of its approach are the same as those which herald the coming of a violent thunderstorm.

During last summer one of us (G. Chatterji) led an expedition to south Bengal to study the upper air conditions associated with nor'westers. On three occasions it was possible to collect some information from soundings by Dines and Chatterji meteorographs. A typical height-temperature graph obtained on one occasion just before the passage of a storm is reproduced in Figure 1. It appears that the nor'wester type of thunderstorms originates through the overrunning of a warm moist southerly or southwesterly wind by a westerly or northwesterly cold air with a high lapse rate. In the present case the cold air orveran the moist air at 2.7 km. and extended to 3.3 km. The air in this layer had a superadiabatic lapse rate of 12° C. per km. while the air underneath was almost saturated and had a lapse rate of 5° C. per km. On all the three occasions the "overrunning" took place in the southeastern quadrant of a low-pressure area which developed a "wind-shift line" more or less defined.

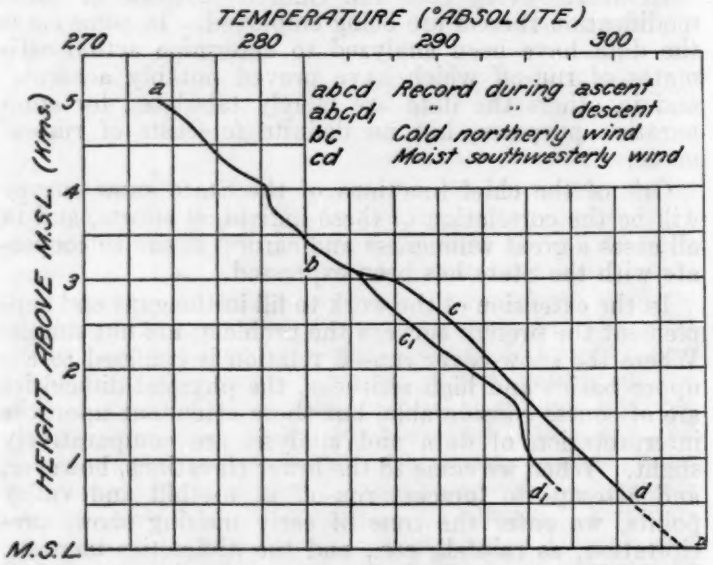

FIGURE 1.—Upper air soundings over Jhikargacha, Bengal, on May 17, 1929, at 17 hr. 35 m. I. S. T., just before a nor'wester

Thus the general conditions under which nor'westers occur in Bengal appear to be exactly similar to those giving rise to "tornadic" thunderstorms in the Mississippi Valley of the United States of America (Humphreys, "Physics of the air," p. 344). Upper air soundings on nor'wester days show that there is a marked increase in the absolute humidity of the southerly current from the Bay of Bengal in the afternoon. This probably explains why the nor'wester type of thunderstorms is more frequent during the afternoon than at any other hour of the day.—*S. C. Roy and G. Chatterji.*

A 24-monthly period of rainfall fluctuation in Saragossa.—A statistical examination of the monthly rainfall at Saragossa has revealed a well-marked periodicity of rather more than 24 months.[1] Saragossa is to the south of the Pyrenees in the valley of the river Ebro in the center of the Province of Aragon. In this region the summer and winter rains are about equal, but on the average the spring fall exceeds that of the summer and the autumn that of the winter. In order to eliminate this seasonal variation the rainfall values for successive 12 months have been examined for the period 1910 to 1924. When these values are plotted the recurrence of maximum values and minimum values at intervals of 12 months is clearly demonstrated. The periodicity is given as rather more than 24 months, although less than 25 months. It is also noted that harmonic analysis has not revealed the existence of smaller components of this value.

It is interesting to recall that in the case of our own country, where longer records are available, it has been shown that the 2-year recurrence is really compounded of two periodicities of 1.7 and 2.1 years, both of which have persisted with very little change through two centuries at least.—*J. Glasspoole.*

On the cause of banner clouds.—Dr. Roderick Peattie has recently described numerous observations of his on certain banner clouds in southern France.[2] He found no support for the explanation of banner clouds as a result either of reduced pressure in the lee of a peak which by expansional chilling of the passing air produces cloud, or from chilling of the wind by the peak. What he saw was the formation of convectional clouds in ascending currents of valleys in the lee of the wind at the level of the peak. These ascending currents, more humid than the

[1] *Sobre un Periodo de unos veinticuatro meses para la fluctuatión de la precipitatión en Zaragoza*, by José Domingo y Quílez; Madrid, An. Soc. Española Meteor., 2, 1928, pp. 9–15.

[2] R. Peattie, Nuages en bannière—Petite etude des vents et des nuages de montagne. Revue de Geographie Alpine, Vol. XVII, 1929, p. 329-335, 3 figs.

wind at the peak, would often be marked by cloud formation when the general wind was clear. These valley clouds ascended to the peak, and there their tops were blown out in banner formation. Doctor Peattie described how while warming himself in the sunlight on a mountain top he could put his hand into the banner cloud, so close did it hug the peak.—*C. F. B.*

The problem of aridity.—About one-third of the globe, with a rainfall averaging less than 10 inches a year, is actually desert, while another third, with less than 20 inches, is unfit or barely fit for agriculture. The existence of this vast area of unprofitable land is a thorn in the flesh of humanity, and there is an almost universal feeling, based partly on sentiment and partly on economic considerations, that more and more of it should be reclaimed and made fit for use and habitation. This feeling has found expression in the United States in the building of many costly dams, reservoirs, and irrigation canals in selected regions of the arid and semiarid West.

These elaborate installations appear, with some exceptions, to justify their existence on several grounds. They have brought extremely fertile soil under cultivation, they have permitted the raising on a large scale of crops that could not be so successfully raised, with or without irrigation, in other parts of the country, and, by making the land habitable, they have promoted the development of various industries and the utilization of natural resources that might otherwise have remained untouched.

Doubtless the conquest of the desert will go on, yet it seems likely that the next generation of Americans will devote an even larger share of attention to the task of protecting regions of abundant rainfall from the occasional disaster of drought than to attempt to eke out a normally scanty rainfall elsewhere. Western Europe has set us an admirable example in the irrigation of humid lands. Thus France, with a rainfall normally sufficient in all parts of the country for the needs of agriculture, irrigates more than 6,000,000 acres of her soil, while Italy, another generally well-watered land, irrigates 4,500,000.—*C. F. Talman in "Why the Weather?" a Science Service Feature.*

Meteorological summary for Chile, September, 1929 (by J. Bustos Navarrete, Observatorio del Salto, Santiago, Chile).—In this month there was moderate activity in atmospheric circulation. Rains were rather rare in the central zone, but somewhat more frequent in the southern zone.

The main depressions bringing periods of unsettled weather and rain were charted as follows: 14th–18th, crossing the southern part of the continent, accompanied by rain in the southern and by cloudy, changeable weather in the central zione; 19th–21st, also crossing the extreme southern region and prolonging the period of unsettled conditions caused by the preceding depression. This latter storm brought general rains in the south and the rain extended as far north as Santiago on the morning of the 20th. Lastly, there was the depression of the 26th–29th, which affected conditions over the southern and central regions and was attended by generally foul weather and heavy rains from Chiloe to Aconcagua.

The most important anticyclonic centers accompanied by fine weather were mapped as follows: 2d–4th, 4th–5th, 7th–11th, and 23d–25th. All of these moved from southern Chile toward Argentina.—*Translated by W. W. R.*

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SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING OCTOBER, 1929

By HERBERT H. KIMBALL, Solar Radiation Investigations

For a description of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1929, **57**: 26.

Table 1 shows that solar radiation intensities averaged below the normal values for October at Madison, Wis., and Lincoln, Nebr., and close to normal at Washington, D. C.

Table 2 shows an excess in the total solar radiation (direct + diffuse) received on a horizontal surface at Washington, close to normal at Madison, and a deficiency at Lincoln, Chicago, and New York.

Skylight polarization measurements obtained on nine days at Washington give a mean of 53 per cent and a maximum of 66 per cent on the 17th. At Madison, measurements obtained on seven days give a mean of 60 per cent, with a maximum of 70 per cent on the 17th. The mean values obtained at the two stations are below their respective October normals, but their maximum values are close to their respective average maxima.

TABLE 1.—*Solar radiation intensities during October, 1929*

[Gram-calories per minute per square centimeter of normal surface]

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1]1.0	2.0	3.0	4.0	5.0	e.
Washington, D. C.											
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Oct. 8	6.27	0.57	0.76	0.96	1.18	1.45					4.57
Oct. 9	4.95					1.00	0.83	0.69	0.48		4.17
Oct. 11	5.79	0.66	0.75	0.86							4.75
Oct. 12	7.29		0.76	0.92	1.07						7.87
Oct. 16	6.76	0.51									7.57
Oct. 17	6.02	0.73	0.86	0.90	1.04		1.18	1.12	0.94	0.84	3.99
Oct. 18	3.45	0.90	0.97	1.09	1.26	1.46	1.14	0.95	0.83	0.76	3.45
Oct. 19	6.02	0.79	0.86	1.02	1.13		1.05	0.87	0.71		3.15
Oct. 23	7.29	0.89	0.98	1.05	1.19		1.18	0.98	0.79	0.65	6.50
Oct. 24	6.76	0.57	0.69	0.86	1.06						4.37
Oct. 26	5.16	0.80	0.90	1.05	1.25	1.51	1.20	1.03	0.89		3.30
Oct. 28	5.56		0.92	1.02	1.14						4.95
Means		0.72	0.84	0.97	1.15	1.36	1.10	0.94	0.77	0.75	
Departures		−0.04	±0.00	+0.02	+0.04	−0.05	−0.01	+0.01	−0.03	+0.05	
Madison, Wis.											
Oct. 1	6.50				1.21						4.57
Oct. 2	6.50		0.72	0.86	1.02						6.76
Oct. 5	5.16		0.83	1.00	1.15						7.04
Oct. 7	6.27		0.82	0.91	1.03	1.39					5.16
Oct. 8	5.79		0.71	0.85	1.12	1.34					4.17
Oct. 14	6.02	0.77	0.89	1.04		1.34	1.18				6.02
Oct. 15	7.04			0.88	1.14		1.23				10.21
Oct. 16	8.81			1.07	1.25	1.46					6.27
Oct. 17	6.27	0.80			1.16		1.23				4.75
Oct. 18	5.16	0.75	0.84	0.97							5.79
Oct. 21	5.16			0.93							5.36
Oct. 24	4.57				1.44						4.37
Oct. 25	3.81			1.04							5.16
Means		0.77	0.89	0.96	1.17	1.38	1.21				
Departures		−0.01	−0.13	−0.09	−0.02	−0.02	+0.02				
Lincoln, Nebr.											
Oct. 5	9.14								0.84	0.71	9.83
Oct. 7	6.76					1.39	1.12	0.83	0.77		7.87
Oct. 12	5.79		0.98	1.10	1.27	1.44	1.25	1.08	0.89	0.78	6.02
Oct. 13	9.14						1.22	0.99	0.92	0.80	8.81
Oct. 14	9.47		0.74	0.90	1.08		1.17	1.02	0.90	0.78	12.24
Oct. 16	10.59		0.99	1.12	1.29	1.50	1.26	1.06	0.93	0.81	10.21
Oct. 17	7.04		0.89	1.05	1.22	1.41	1.13	0.93	0.77	0.66	9.83
Oct. 24	4.17			1.12	1.29						5.36
Oct. 25	4.17			1.17	1.37		1.33	1.20	1.08	0.94	4.95
Oct. 26	4.17	0.59	0.72	1.03	1.22		1.30	1.09	0.98	0.80	5.56
Means		(0.59)	0.86	1.07	1.25	1.44	1.22	1.02	0.90	0.78	
Departures		−0.28	−0.08	−0.03	−0.03	−0.04	−0.03	−0.06	−0.05	−0.05	

[1]Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface*

[Gram-calories per square centimeter of horizontal surface]

Week beginning	Average daily radiation								Average daily departure from normal				
	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Fresno	La Jolla	Washington	Madison	Lincoln	Chicago	New York
1929	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Oct. 1	252	323	302	236	150	459	423	374	−69	+51	−24	+22	−97
Oct. 8	402	189	206	147	247	407	432	293	+100	−58	−94	−42	±0
Oct. 15	308	245	285	193	221	349	388	217	+34	+22	−17	+25	+23
Oct. 22	272	188	288	120	180	343	349	281	+8	−17	+18	−39	−8
Excess or deficiency since first of year on Oct. 28									+6,300	−553	−4,122	−686	−5,943

POSITIONS AND AREAS OF SUN SPOTS

Communicated by Capt. C. S. Freeman, Superintendent U. S. Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, and Mount Wilson Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1929	*h. m.*	°	°	°			
Oct. 1 (Mount Wilson)	12 45	−45.0	219.5	+10.0		185	
		+15.0	279.5	+11.0		254	
		+52.0	316.5	+14.0		11	450
Oct. 1 (Yerkes)	9 56	−50.5	215.6	+12.8		133	
		−47.3	218.8	+10.5	24		
		−44.8	221.3	+11.3		121	
		−43.3	222.8	+9.9		54	
		−39.3	226.8	+10.8	17		
		+8.8	274.9	+8.7	27		
		+9.6	275.7	+10.2		141	
		+10.2	276.3	+10.1	20		
		+10.8	276.9	+10.0	20		
		+11.2	277.3	+12.3	31		
		+16.2	282.3	+10.4		173	
		+20.1	286.2	+10.5	97		
		+52.2	318.3	+12.9	14		872
Oct. 2 (Mount Wilson)	13 15	−30.0	221.0	+11.0		248	
		+30.0	281.0	+12.0		216	
		+68.0	319.0	+15.0		22	486
Oct. 2 (Yerkes)	15 37	−36.2	213.5	+13.1		106	
		−33.2	216.5	+10.3	16		
		−28.6	221.1	+10.7		377	
		−25.7	224.0	+11.5		147	
		−22.8	226.9	+11.0		215	
		+23.8	273.5	+9.4	22		
		+24.9	274.6	+10.7		117	
		+28.9	278.6	+10.7	15		
		+34.1	283.8	+11.0	104		
		+36.0	285.7	+11.7	123		
		+67.0	316.7	+13.2	20		1,262
Oct. 3. (Naval Observatory)	10 38	−52.0	187.3	+13.5		15	
		−25.5	213.8	+12.0		62	
		−15.0	224.3	+10.5		340	
		+42.0	281.3	+10.5		185	
		+79.0	318.3	+12.5		62	664
Oct. 4 (Naval Observatory)	11 44	−38.0	187.5	+12.5	6		
		−12.0	213.5	+12.5		46	
		−1.0	224.5	+10.0		370	
		+57.0	282.5	+10.5		154	576
Oct. 5 (Naval Observatory)	12 13	−38.0	174.0	−5.0		22	
		−24.0	188.0	+13.0		31	
		+2.0	214.0	+13.0		18	
		+13.0	225.0	+10.0		401	
		+70.5	282.5	+11.0		154	626
Oct. 6 (Naval Observatory)	10 31	−55.0	144.8	−19.5		55	
		−31.0	168.8	−8.0	6		
		−12.5	187.3	+13.5		52	
		+26.0	225.8	+10.5		386	
		+83.0	282.8	+11.5		139	638
Oct. 7 (Naval Observatory)	10 44	−76.0	110.5	−10.5	324		
		−73.0	113.5	+5.0		46	
		−42.5	144.0	−18.5		62	
		+2.0	188.5	+14.0		25	
		+39.5	226.0	+11.0		417	874
Oct. 8 (Naval Observatory)	10 52	−62.5	110.7	−10.5	340		
		−57.5	115.7	+4.5		139	
		−30.0	143.2	−20.0		170	
		+16.0	189.2	+13.5		12	
		+55.0	228.2	+11.5		432	1,093

Positions and areas of sun spots—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1929	h. m.	°	°	°			
Oct. 9 (Naval Observatory).	10 32	−49.5	110.7	−11.0	478		
		−45.0	115.2	+4.5		170	
		−15.5	144.7	−20.0		201	
		+10.5	170.7	−8.5		22	
		+69.0	229.2	+11.0		494	1,365
Oct. 10 (Naval Observatory).	10 43	−36.0	110.9	−11.0	494		
		−31.0	115.9	+4.0		231	
		−2.0	144.9	−20.0		355	
		+23.0	169.9	−8.5		77	
		+82.0	228.9	+11.5		478	1,635
Oct. 11 (Naval Observatory).	10 45	−22.5	111.2	−11.0	463		
		−17.5	116.2	+4.0		340	
		+11.5	145.2	−20.0		556	
		+36.0	169.7	−8.0		15	1,374
Oct. 12 (Naval Observatory).	10 42	−9.0	111.5	−11.0	448		
		−4.5	116.0	+4.0		417	
		+25.0	145.5	−19.5		741	1,606
Oct. 13 (Naval Observatory).	10 42	+4.0	111.3	−11.0	432		
		+9.5	116.8	+4.0		355	
		+38.0	145.3	−20.0		617	1,404
Oct. 14 (Naval Observatory).	10 54	+17.5	111.5	−11.0	556		
		+22.5	116.5	+4.5		309	
		+50.5	144.5	−20.0		694	1,559
Oct. 15 (Naval Observatory).	13 30	+31.5	110.9	−11.0	571		
		+38.0	117.4	+4.5		278	
		+66.0	145.4	−21.0		617	1,466
Oct. 16 (Naval Observatory).	10 47	+43.5	111.2	−11.0	540		
		+51.0	118.7	+4.0		216	
		+78.0	145.7	−21.0		556	1,312
Oct. 17 (Naval Observatory).	10 42	−3.0	51.6	−12.0		22	
		+57.5	112.1	−11.5	586		
		+68.0	122.6	+3.0		185	793
Oct. 18 (Naval Observatory).	13 14	−73.0	327.0	+12.0	9		
		−3.0	37.0	−9.0		18	
		+10.5	50.5	−12.5	9		
		+71.5	111.5	−12.5	617		
		+82.5	122.5	+2.0	170		823
Oct. 19 (Naval Observatory).	10 41	−61.5	326.7	+11.5	6		
		+10.0	38.2	−9.0		18	
		+23.5	51.7	−11.5		12	
		+84.5	112.7	−11.0	617		653
Oct. 20 (Naval Observatory).	10 39	−54.0	321.0	+8.0	6		
		+24.0	39.0	−9.0		31	
		+38.0	53.0	−11.0		68	105
ct. 21 (Naval Observatory).	11 9	−72.0	289.6	+12.0	68		
		+38.5	40.1	−9.5	9		
		+52.5	54.1	−10.5		46	123
Oct. 22 (Naval Observatory).	14 14	−57.5	289.2	+11.5	46		
		+68.5	55.2	−11.5	6		52
Oct. 23 (Naval Observatory).	10 40	−46.5	289.0	+11.5	46		
		+33.5	9.0	−15.5		12	58
Oct. 24 (Naval Observatory).	10 46	−83.0	239.2	+9.0		231	
		−34.0	288.2	+11.5		46	277
Oct. 25 (Naval Observatory).	11 29	−71.0	237.6	+8.5		494	
		−20.5	288.1	+10.5		18	
		+17.0	325.6	+9.0	3		515
Oct. 26 (Naval Obesrvatory).	10 39	−59.0	236.9	+8.5		586	
		−32.5	263.4	+13.5		18	
		−8.5	287.4	+12.0		9	
		+30.0	325.9	+8.5		25	638

Positions and areas of sun spots—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1929	h. m.	°	°	°			
Oct. 27 (Naval Observatory).	10 41	−46.5	236.2	+9.0		540	
		−18.0	264.7	+13.5		216	
		+4.0	286.7	+11.5		12	
		+40.5	323.2	+9.5		77	845
Oct. 28 (Naval Observatory).	10 41	−54.5	215.0	−21.5		12	
		−33.5	236.0	+9.0		586	
		−4.0	265.5	+13.0		355	
		+53.5	323.0	+8.5	31		
		+71.0	340.5	−11.0		22	1,006
Oct. 29 (Mount Wilson)	12 40	−71.0	184.2	+15.0	8		
		−20.0	235.2	+10.0		940	
		+10.0	265.2	+15.0		680	
		+68.0	323.2	+11.0		6	1,634
Oct. 30 (Mount Wilson)	13 15	−69.0	172.7	+3.0	10		
		−60.0	181.7	+15.0		29	
		−5.0	236.7	+10.0		1,218	
		+22.0	263.7	+15.0		236	1,493
Oct. 31 (Naval Observatory).	14 19	−53.5	174.4	+4.0	12		
		−46.5	181.4	+16.0		93	
		+9.5	237.4	+9.5		571	
		+36.5	264.4	+13.5		293	969
Mean daily area for October, Naval Observatory and Mount Wilson.							875
Mean daily area for October, Naval Ovservatory and Yerkes.							913

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR OCTOBER, 1929 [1]

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich Switzerland]

October, 1929	Relative numbers	October, 1929	Relative numbers	October, 1929	Relative numbers
1	47	11	77	21	32
2	53	12	b 79	22	22
3	64	13	b 78	23	33
4	b 55	14	63	24	d 17
5	55	15	56	25	
6	Ec 64	16	40	26	Mc 36
7	d 74	17	37	27	Mc 68
8	68	18	26	28	a 97
9	76	19	18	29	57
10	b 84	20	19	30	b 76
				31	Ec 69

Mean, 30 days=54.7.

1=Dependent alone on observations at Zurich and its station at Arosa.
a=Passage of an average-sized group through the central meridian.
b=Passage of a large group through the central meridian.
c=New formation of a large or average-sized center of activity; E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d=Entrance of a large or average-sized center of ativity on the east limb.

AEROLOGICAL OBSERVATIONS

By RICHMOND T. ZOCH

Free-air temperatures were below normal at all levels at Broken Arrow, Due West, and Groesbeck and in the lower levels at Royal Center. Free-air temperatures in the upper levels at Royal Center and at all levels at Ellendale were above normal. (See Table 1.)

Free-air relative humidity departures were variable at all of the aerological stations excepting Broken Arrow, where there was a large positive departure at all levels. Vapor-pressure departures also were variable at all stations excepting Broken Arrow, where they were above normal.

In the lower levels the resultant winds had a southerly component except in the Southeastern States. (See Table 3.) Above 1,000 meters the resultant winds were from the northwest east of the Rocky Mountains. On the Pacific coast the resultant winds were variable.

The kite flight at Ellendale on October 15 is very interesting, in that there was a pronounced inversion up to 107 meters above the surface. Through this stratum the temperature rose 17.4° C., a remarkable increase for this season of the year. A well-defined mirage was observed at the time of this observation.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during October, 1929*

TEMPERATURE (° C.)

Altitude Meters m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)		Washington, D. C. (naval air station) (7 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	16.7	−0.2	14.5	−1.8	8.6	+1.4	17.4	−1.6	10.2	−2.9		
500	15.6	−0.2	13.7	−0.8	9.1	+1.8	16.6	−1.3	9.3	−2.5		
1,000	13.4	−0.4	12.2	−0.1	8.7	+2.1	14.7	−1.0	7.9	−1.4		
1,500	11.1	−0.7	9.9	−0.2	6.4	+1.4	12.8	−0.9	6.3	−0.6		
2,000	8.7	−0.9	7.9	−0.4	3.6	+0.8	10.6	−0.9	4.5	+0.1		
2,500	6.1	−0.9	5.7	−0.6	0.7	+0.4	8.3	−0.9	2.3	+0.2		
3,000	4.0	−0.2	3.4	−0.6	−2.2	+0.3	6.1	−0.8	0.3	+0.7		
4,000	−1.0	+0.2			−6.3	+1.8	1.7	−0.2	−4.1	+1.5		
5,000					−11.3	+2.2						

RELATIVE HUMIDITY (%)

Surface	71	+4	72	+7	67	−1	77	+3	73	+4		
500	69	+6	63	0	63	−3	69	+1	69	+4		
1,000	68	+9	63	+1	51	−7	60	−5	66	+4		
1,500	70	+15	61	+3	51	−2	53	−7	58	+1		
2,000	67	+17	52	+1	50	0	48	−6	52	−1		
2,500	65	+19	49	+3	50	+2	52	+4	50	+2		
3,000	56	+13	45	+2	47	+1	63	+21	51	+6		
4,000	46	+10			36	−9	86	+47	31	−11		
5,000					32	−10						

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during October, 1929*—Continued

VAPOR PRESSURE (*mb*).

Altitude Meters m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)		Washington, D. C. (naval air station) (7 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	13.86	+0.69	11.99	−0.65	7.20	+0.25	16.01	−0.80	9.02	−1.65		
500	12.60	+0.89	10.23	−0.92	7.07	+0.24	13.83	−0.75	8.17	−1.19		
1,000	10.71	+1.03	9.30	−0.20	5.40	−0.36	10.71	−1.40	7.11	−0.46		
1,500	9.37	+1.45	7.73	+0.19	4.52	−0.19	8.18	−1.47	5.53	−0.41		
2,000	7.66	+1.58	5.54	−0.12	3.61	−0.28	6.73	−0.58	4.45	−0.22		
2,500	6.28	+1.64	4.41	−0.01	2.91	−0.28	6.13	+0.60	3.68	+0.10		
3,000	4.77	+1.22	3.40	−0.16	2.12	−0.46	6.11	+1.97	3.18	+0.33		
4,000	2.83	+0.93			1.04	−0.66	5.60	+2.93	1.12	−0.63		
5,000					0.42	−0.63						

TABLE 2.—*Free-air data determined at naval air stations during October, 1929*

Altitude (meters), m. s. l.	Temperature (° C.)			Relative humidity (%)		
	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.
Surface	16.7	20.5	11.3	78	61	72
500	16.9	19.1	10.6	68	57	58
1,000	15.4	18.4	8.8	15	45	54
2,000	12.4	14.4	5.2	54	29	52
3,000	8.0		2.6	45		32
4,000	2.2			42		

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during October, 1929*

Altitude m. s. l.	Broken Arrow, Okla. (233 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,868 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (65 meters)		Key West, Fla. (11 meters)		Los Angeles, Calif. (40 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°	
Surface	S 9 W	0.4	S 27 W	1.8	N 62 W	3.4	N 17 E	1.4	N 51 W	1.5	N 5 W	0.2	S 85 W	1.0	N 4 W	1.7	N 58 E	2.7	N 72 W	2.4
500	S 1 E	1.7	S 45 W	4.4			N 37 E	2.6	N 71 W	1.8	S 11 E	1.0			N 47 E	2.3	N 75 E	5.5	S 78 E	0.1
1,000	N 86 W	2.2	S 75 W	4.2			N 1 E	1.0	N 60 W	2.6	S 78 W	1.0	S 64 W	4.7	N 47 E	2.1	N 78 E	3.0	N 55 W	0.4
1,500	N 65 W	4.3	S 87 W	6.7			N 87 W	1.7	N 53 W	4.1	N 60 W	2.8	N 83 W	5.2	N 68 W	0.5	S 78 E	2.0	N 53 E	0.2
2,000	N 65 W	5.0	S 79 W	6.4	N 75 W	5.0	N 73 W	5.0	N 50 W	7.0	N 69 W	3.3	N 80 W	5.4	N 62 W	1.7	S 50 E	1.6	S 40 E	0.4
2,500	N 55 W	5.7	S 80 W	7.8	N 64 W	7.1	N 60 W	6.6	N 55 W	8.7	N 55 W	6.0	N 72 W	6.9	N 77 W	3.2	S 21 E	1.8	N 22 E	0.9
3,000	N 64 W	6.6	N 69 W	8.3	N 58 W	6.8	N 51 W	7.7	N 57 W	10.2	N 71 W	5.6	N 78 W	5.7	N 81 W	4.4	S 21 W	1.6	N 9 E	0.2
4,000	N 57 W	6.3	N 81 W	8.6	N 64 W	5.9	N 51 W	9.9	N 52 W	13.1	N 68 W	1.5	S 89 W	5.9	N 86 W	6.5	S 61 W	5.2	N 60 W	3.2
5,000					N 37 E	1.0	N 62 W	10.2	N 57 W	13.4			S 80 W	8.5	N 85 W	9.3	S 67 W	6.1	S 32 E	3.9

	Medford, Oreg. (446 meters)		Memphis, Tenn. (145 meters)		New Orleans, La. (25 meters)		Omaha, Nebr. (313 meters)		Royal Center, Ind. (225 meters)		Salt Lake City, Utah (1,280 meters)		San Francisco, Calif. (60 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (67 meters)		Washington, D. C. (34 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°	
Surface	S 21 E	1.0	N 50 W	0.2	N 26 E	1.9	N 15 E	0.2	S 13 W	0.9	S 46 E	1.9	N 46 E	0.5	N 7 E	1.2	S 72 E	1.5	N 66 W	0.2
500	S 11 W	0.9	N 11 W	0.3	N 59 E	5.2	S 75 W	1.3	S 88 W	2.2			N 18 W	1.7	N 7 W	0.7	S 18 W	3.3	N 86 W	3.7
1,000	S 34 E	0.4	N 35 W	3.5	N 44 E	3.3	N 67 W	3.0	N 52 W	4.2			N 4 W	3.3	N 34 W	3.9	S 36 W	4.7	N 81 W	5.5
1,500	S 42 E	1.8	N 49 W	5.8	N 12 W	3.6	N 57 W	5.1	N 46 W	6.1	S 24 E	3.2	N 1 W	1.5	N 35 W	7.3	S 35 W	8.8	N 78 W	7.9
2,000	S 40 W	1.5	N 58 W	6.5	N 39 W	5.8	N 50 W	6.2	N 37 W	8.3	S 15 E	1.4	N 32 E	0.8	N 41 W	9.1			S 83 W	8.3
2,500	S 51 W	2.3	N 75 W	7.3	N 48 W	5.8	N 52 W	8.1	N 47 W	9.9	N 87 W	1.0	N 88 E	0.6	N 43 W	8.9			S 63 W	10.8
3,000	S 63 W	2.8	S 73 W	5.5	N 36 W	4.6	N 39 W	9.0	N 54 W	12.5	N 71 W	2.5	S 17 W	1.9	N 59 W	9.5			S 76 W	13.0
4,000	S 66 W	4.0			N 40 W	1.8	N 48 W	9.3	N 56 W	14.8	N 59 W	4.1	S 73 W	3.4						
5,000	N 89 W	3.0			S 58 W	1.3					N 48 W	4.7								

TABLE 4.—*Observations by means of kites, captive and limited-height sounding balloons, during October, 1929*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes (meters), m. s. l., reached during month	2,671	2,329	2,841	2,470	2,676
Maximum altitude (meters), m. s. l., reached and date	[1] 4,081	[2] 3,481	[3] 5,090	[4] 4,867	[5] 4,897
Number of flights made	30	29	27	20	26
Number of days on which flights were made	29	28	26	20	25

[1] 26th. [2] 13th. [3] 3d. [4] 22d. [5] 25th.

In addition to the above there are approximately 120 pilot balloon observations made daily at 50 Weather Bureau stations in the United States.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By P. C. DAY

GENERAL SUMMARY

October, 1929, was marked by two rather unusual storm periods, the first being a continuation of the tropical storm that was central over western Florida at the end of September after an unusual course around the southern end of that State, whence it moved northeastward near the Atlantic coast during the first few days of October, attended by unusually heavy rains, high winds, and floods in its more southern course; and the other, which pursued a somewhat erratic course, reaching Georgia from the middle plains, whence it moved northward and westward to the vicinity of Lake Michigan in the early part of the last decade, as a storm of unusual violence, attended by much loss of life and damage to property on and near that and some near-by lakes.

Aside from the above, the month was mainly free from adverse weather, and it had many days favorable for the pursuit of the usual activities incident to the mid-autumn month.

PRESSURE AND WINDS

The tropical storm previously mentioned moved sharply from western Florida to the northeastward by the morning of October 1, and thence pursued a general northeasterly course over the Atlantic Coast States, reaching New England by the morning of the 4th. A full account of this storm appears on pages 418–421 in this REVIEW. Following this storm, generally favorable conditions existed save for local precipitation, until the beginning of the second decade, when light precipitation overspread the north and central districts from the Plains States eastward to near the Great Lakes and Ohio Valley, and local precipitation occurred over the Florida Peninsula, nearly 5 inches of rain falling at Miami during the 24 hours ending 8 a. m., the 11th, and additional amounts of about 3½ inches occurred during the following two days. The rain condition over the Plains States developed a cyclonic formation by the morning of the 12th, and precipitation continued over the more eastern portion of the rain area, the general storm moving northeastward into Canada by the morning of the 13th, while rain overspread many districts from the Great Lakes and Ohio Valley eastward.

The remainder of the second decade was chiefly free from important precipitation until at the close a cyclonic condition had developed in the middle plains, and by the morning of the 21st it had moved southeastward to central Georgia, combining with a tropical disturbance that had moved from southern Florida, whence it turned sharply to the northward, developing important strength and reaching central Ohio by the following morning; thence it moved northwesterly to central Michigan and continued in that general locality until the morning of the 24th, after which it moved easterly and rapidly dissipated. This storm was attended by heavy rains and some snows throughout its northerly course and, as stated previously, attained great severity in the vicinity of Lake Michigan, attended by high winds, causing much damage to property near or on that and portions of near-by lakes. A number of vessels were wrecked due to the severe weather existing, and approximately half a hundred lives were lost.

During the last few days of the month cyclonic conditions existed over much of the country, low pressure being central on the morning of the 28th over Colorado, with more or less precipitation to the northwest and southeast of that State. During the 29th the storm center over Colorado remained mainly stationary and was augmented by another low-pressure area from the far Southwest, and precipitation continued over many of the districts where it had occurred on the previous day and extended farther eastward and northward. By the morning of the 30th the storm center had lost some energy, and a new cyclone had developed over southern Texas, and the rain area, mostly light, had extended eastward to near the Atlantic coast. On the 31st the main storm area was central in the upper Mississippi Valley, the one over southern Texas had remained nearly stationary, and precipitation had extended to nearly all parts of the country save the Southwest and far West, snow was falling in much of the northern mountain and Great Plains regions, and rainy or foggy conditions prevailed over large portions of the remaining areas to eastward and southward.

Anticyclonic conditions existed during much of the month over the far western districts, and cyclonic action was weak in the Pacific Coast States, few storms of importance originating or passing over that district during the month.

The sea-level averages of pressure were mainly above normal over the Great Plains, and thence to the far Northwest. They were below normal mainly over the eastern and southeastern districts and in interior and southern California.

Compared with September values, the mean pressure was lower from the Great Lakes and Ohio Valley eastward, and higher over other parts of the country, the increases being particularly large from the Great Plains westward.

The winds were mainly moderate, and no high velocities were recorded save in connection with the storm early in the month over the southeastern districts and that of the 22d and 23d in the vicinity of Lake Michigan.

Few tornadoes were reported and almost no deaths were caused by direct action of the winds, though about 50 lives were lost from drowning, due to stress of weather on Lake Michigan.

TEMPERATURE

The month was moderately cool over most districts east of the Mississippi River, and warmer than normal to the westward, though the departures in both directions were unimportant. No unusually low temperatures were experienced, and killing frosts generally did not occur ahead of the usual period, and in the Mississippi Valley were not reported south of St. Louis, Mo.

By weeks, the averages of temperature were about as follows: For the first week they were, as a whole, much below normal in practically all sections from the Mississippi Valley eastward, while from the Rocky Mountains westward abnormally warm weather prevailed in general, though the week was only slightly warmer than normal over the North Pacific coast, and nearly normal warmth prevailed in the Great Plains.

The week ending October 15 continued cooler than normal over most central and northern districts, from the Mississippi River eastward, and it continued warm in the West, and was generally warmer than normal in the southern districts east of the Mississippi River, the week

averaging from 3° to 6° above normal over many of the southern plains, mountain, and plateau districts.

The week ending October 22 was warm throughout the entire country, save locally near the Atlantic coast from Florida to New England. The week was decidedly warm over most central and northern districts from the Great Plains westward, particularly so in some of the more northern sections where the positive departures ranged up to as much as 12°. The last decade of October was on the whole moderately warm from the Dakotas westward and southwestward to the Pacific coast, and also over the Northeast. The week was cooler than normal over the remaining sections, and decidedly so in the South, particularly from central Texas westward to Arizona, where the averages ranged from 6° to as much as 12° below normal.

The warmest periods of the month were mainly during the first decade in the regions from the Great Plains westward and over the Gulf and South Atlantic States, and during the second decade over the remaining portions, save in Oregon, where the warmest period was about the 21st.

Maximum temperatures were above 100° at a few points in the Southwest, the highest reported being 109° in Arizona, and they did not go higher than 80° in the more northern sections.

The lowest temperatures occurred mainly during the last decade, though in portions of the Northeastern States they occurred at the beginning of the second decade. The lowest reported, 5° below zero, occurred in the mountains of Colorado, and readings below zero were reported from a few other Mountain States. As a rule, freezing temperatures did not occur over extensive areas until the main crops had matured, but temperatures of 32° or lower were recorded at some time during the month at exposed points in all the States save Florida.

PRECIPITATION

The greater part of the country had precipitation in excess of the normal, this being particularly the case in the East Gulf and South Atlantic States, and in Missouri and portions of near-by areas. In North Carolina the average fall for the State was the greatest of record for October, and West Virginia had an average only slightly less than that of October, 1925, the previous highest record for October.

Some unusually heavy individual monthly amounts were reported from points in a number of States, the largest reported, 20.18 inches, occurring at Miami, Fla., where floods and overflow from near-by Lake Okeechobee practically destroyed all truck crops in that region. Precipitation in excess of 10 inches was also reported from points in other Southern and Eastern States, where the precipitation was largely confined to two periods, that near the first of the month and that about the beginning of the third decade.

In the far West precipitation was practically everywhere less than normal and in the far Northwest, notably in portions of Washington and Oregon, the drought that had existed during preceding months was still unbroken at the end of October, some stations reporting the combined precipitation for the four months, July to October, inclusive, as the least of record for those months in the history of the stations. The springs in many portions of this region have gone dry, the water supply has become seriously reduced, and the winter feed outlook has been greatly affected.

SNOWFALL

The snowfall exceeded the October average amounts over extensive regions. Near and to eastward of the Mississippi River the principal snowfall came during the 22d to 24th. Considerable portions of eastern Iowa, northern Illinois, and southern Wisconsin received from 5 to 8 inches at this time. This snow reached some southern counties of the States just north of the Ohio River, and a very small portion of Kentucky. From eastern West Virginia northeastward to southern New York snowfall was practically confined to the high portions and was not heavy for the place and season. In northern New York and New England a few points had monthly amounts in excess of a foot. In the western half of the country substantially all the October snowfall came within the final five days. In the Plains States, from southeastern Nebraska southward and southwestward, only the highest portions received any snow; but northwestern Nebraska and most parts of the Dakotas had comparatively heavy falls. This was true also of most of Colorado and southern and eastern Wyoming, where a few stations measured 2 feet or slightly more. Even as far south as far-western Texas one elevated station had 8 inches.

The eastern portion of the plateau region had moderate snowfall at the higher elevations, but the western portion of this area, and the Cascade-Sierra and other far-western mountains had hardly any snowfall.

RELATIVE HUMIDITY

The monthly percentages of relative humidity were above the normal over large portions of the Great Plains, but elsewhere throughout the country deficiencies were the rule, these being well marked over practically all far-western districts, where deficient precipitation was the rule, and drought conditions have prevailed for several months. Here, the fire hazard has been acute and continued so at the end of the month.

SEVERE LOCAL STORMS, OCTOBER, 1929

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the annual report of the chief of bureau]

Place	Date	Time	Width of path, yards [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Blackville, S. C.	1			1	$3,500	Tornado	Considerable damage to property over short path; 4 persons injured.	Official, U. S. Weather Bureau.
Atlantic Coast States (central and southern).	1-2					Wind and rain	Heavy damage to crops and property in path of tropical hurricane.	Do.
Oswego, N. Y., and vicinity.	2-3					Wind	Lake-front property and telephone and light wires damaged.	Do.
St. Johns River, Fla. (near mouth).	10				25,000	High winds	British schooner blown ashore, with some damage to vessel.	Do.
Beckham County, Okla. (northwestern).	11	4:30 p. m.	3,520		35,000	Hail	Considerable damage to crops and other property over path 10 miles long.	Do.
Clinton, Tex. (near)	15	2-3 p. m.	3 mi.			do	Young crops destroyed; roofs, windows, and auto tops damaged; path 5 miles.	Do.
Pennsylvania (central)	21-22	4-10 p. m.				Wind and rain	Shamokin Airport damaged; wire service of all kinds impaired; trees uprooted; crops injured.	Do.
Lake Huron and Lake St. Clair (shores of).	21-23			1		Wind	4 large boats driven ashore, some in bad shape, with cargoes total loss; much damage to waterfront property.	Do.
Lake Michigan (southern shores of).	22-24			46		do	Several million dollars' damage to lake-front property and shipping; car ferry Milwaukee sunk, causing considerable loss of life.	Do.
Illinois (northern) and Wisconsin (eastern).	28-29			10		do	Steamship Wisconsin foundered, causing loss of life; heavy damage to parks, buildings, and other property on lake front.	Do.
Anderson, Tex. (near)	30		50			Tornado	Schoolhouse wrecked	
Houston, Tex. (vicinity of).	30				5,000	Series of tornadic storms.	Some damage to property; 4 persons injured	Do. Do.
Rylie and Elam, Tex. (near).	30	4-5 p. m.				Wind and hail	Several homes damaged; a number of outbuildings wrecked.	Do.

[1] Mi. signifies miles instead of yards.

RIVERS AND FLOODS

By R. E. SPENCER

Excepting the few slight rises of the 22–24th, all floods in October were more or less direct results of the tropical storm which crossed the extreme southeastern United States and moved northward along the Atlantic seaboard during the first few days of the month. This storm is fully described elsewhere in this review. The resultant rains were practically continuous from September 20 to October 1 in the South Atlantic and East Gulf sections, and during the first two days of October in the Middle and North Atlantic States and the extreme eastern Ohio Valley, with a distinct division, in the Southeast, into two periods, both of which culminated in extremely heavy falls—one on September 26–27 and the other on September 30–October 1.

These two rain periods, the fall in either of which would have been sufficient to produce floods in the rivers of the Southeastern States, were especially effective in combination—the first having brought many of the streams to flood stage in late September and the second, following while they were still high, causing serious overflows.

Most conspicuous among these was the flood, or double flood, in the Savannah River at and below Augusta, Ga. In his report on the first portion of this disastrous rise Mr. E. D. Emigh, the official in charge of the Weather Bureau office at Augusta, pays particular attention to the amount and distribution of the rainfall. He computes the average depth over the Savannah River drainage area (7,294 square miles) for the 34-hour period ending at 8 a. m. September 27, as 8.84 inches and points out that by far the greater part of the rain fell in the central and lower portions of the basin. This meant, of course, that the comparative lightness of rain in the upper basin must have been balanced by a corresponding excess in the middle and lower parts; and the result was that while river stages in the upper basin (specifically at Carlton, Ga., and Calhoun Falls, S. C.) were not extraordinarily high, the river in the central and lower portions reached the highest stages of record.

A suggestion of the rapidity and magnitude of this rise is given in the following extract of Mr. Emigh's report:

At Augusta on the evening of September 25 the Savannah River was at a 10-foot stage, with a discharge of approximately 10,000 cubic feet per second. In 24 hours there was an increase in stage to 33.1 feet and a discharge of 100,000 cubic feet per second. At the end of 48 hours the river, at a crest of 46.3 feet, was carrying thirty-seven times as much water as at the outset and was discharging 370,000 cubic feet per second—the greatest discharge ever known to have passed the city. Warnings of the approach of the flood were of course distributed by every available means, and while considerable nervousness was inevitable there was a fairly general local assurance that the levee could be depended upon to protect the city. This confidence was justified, for the main portion of the levee proved adequate both in capacity and stability to withstand the test. About 3 miles below the city, however, a breach occurred. Fortunately, the break did not attain great width until after the river had fallen considerably from the crest stage. The situation was somewhat relieved by the city engineers, who opened the outlet gates at the mouth of Butlers Creek, and by two breaches in the levee near the Butlers Creek gates. Backwater, however, overflowed much farm land and flowed into the lower sections of the city to a depth of 2 to 4 feet. Since the houses in the area affected were built well above the ground in prelevee days, no great harm was done. Ample warning of the approach of the backwater had been given by the city engineers and disseminated by them, by the newspapers, and by the Weather Bureau office.

In the second portion of this flood (crest 45.1 at midnight of October 2) the rainfall distribution over the Savannah River Basin was more regular and somewhat less heavy than in late September. A comparative table of amounts follows, the stations being arranged in the order of their distances from Augusta:

	34 hours ending 8 a. m. Sept. 27	30 hours ending 6 p. m. Oct. 2
Augusta, Ga.	7.78	9.98
Double Branches, Ga.	14.51	9.80
Edgefield, S. C.	7.84	8.26
Warrenton, Ga.	9.16	6.75
Greenwood, S. C.	9.83	9.02
Washington, Ga.	14.49	9.68
Calhoun Falls, S. C.	9.48	8.30
Carlton, Ga.	7.67	7.12
Gillsville, Ga.	5.95	8.15
Anderson, S. C.	5.50	5.83
Toccoa, Ga.	5.03	4.30
Average	8.84	7.93

The lowest stage reached at Augusta following the crest of 46.3 feet on September 27, was 21 feet late on the

30th—11 feet higher than the stage from which the first flood had begun; so that the extremely heavy rain of September 30–October 1 rendered it immediately evident that a second rise of rapidity and magnitude closely comparable with the first would occur. No great damage had resulted in the city from the first rise; but the levee, softened by the abundance of rain and high water, had been seriously weakened by slides at several points, so that the prospect of this second major flood was considerably more threatening than that of the first had been. The gravity of the situation is sufficiently suggested by the strenuous efforts made by the city to cope with it. The crest forecast, issued at 7 p. m. of October 1, was immediately published in a special edition of the Augusta Chronicle, and while police and fire departments directed the exodus from threatened portions of the city to the hill sections, a small army of volunteers and conscripts was organized for levee-protection work. By 2 a. m. this work, under the direction of Mr. Ralph S. Howard, of the United States Engineer office, and his associates, Mr. T. S. Gray, chairman of the levee commission, and Mr. Elroy G. Smith, was under way; and, in spite of the difficulties imposed by darkness, a rapidly rising river, and a steady downpour of rain, by 8 a. m. the levee had been successfully repaired at its least dependable points. The river, already 10.8 feet above flood stage, continued to rise until the crest of 45.1 feet was reached at midnight of October 2, with the levee still intact except at the point of its break during the first flood.

In reporting on stages and discharge Mr. Emigh remarks:

> Although the crest stage reached on October 2 was but 45.1 feet, as against 46.3 feet on September 27, discharge measurements at Stevens Creek power dam disclosed the fact that the discharge in the October flood was 382,000 cubic feet per second, as against 370,000 in the September flood. The fact that the river carried more water at a lower stage was due to the removal by the first flood of the Hamburg Road embankment, and in some degree to the clearing away of other obstructions further downstream in the same manner, particularly the Charleston & Western Carolina bridge approach.

The two floods merged below Augusta, resulting in an immense accumulation of water in the delta and swamp land of the Coastal Plain. While the Weather Bureau maintains no gages on this reach of the river, it was found possible to make satisfactory forecasts of flood heights at crucial points. This information proved of a special value to railroads, the State highway commission, and the United States Engineer officer supervising precautionary measures in Savannah, Ga., and elsewhere along the lower reaches of the river.

The following discussion of damage and losses is taken from Mr. Emigh's report:

> Backwater from the break in the levee covered an extensive area of farm lands, the city cemeteries, May Park, and about 40 city blocks in the low-lying southeastern portion of Augusta, extending to Union Station and the Federal building. The depth of the water was 2 feet greater than in September. On the lower farm lands it was over 15 feet deep and at lowest points in the city 8 to 10 feet deep. Aside from filling cellars of business houses and churches and creating a situation that called for a sanitary clean-up, the damage in the city was not great. On the farms there was total loss of crops, including stacked and stored hay and other property, while considerable numbers of cattle, mules, and hogs were drowned, and houses, barns, cabins, and farm equipment were carried off, destroyed, or seriously damaged. Advance warnings prevented loss of human life, but the deluge of rain and resulting flooded condition of land and roads prevented the saving of property.
>
> Railways, highways, and bridges suffered so severely that no traffic moved into or out of Augusta for several days after the second flood, which completed the devastation efficiently begun by the first storm, from which only partial recovery had been possible. Conditions were considerably aggravated in many places on both sides of the Savannah River by the breaking of the dams of practically all of the numerous fishing and bathing ponds, and of eight of the power dams in the Horsecreek Valley, in South Carolina. Fortunately the absence of heavy winds prevented the complete destruction of corn, cotton, and other standing crops outside the actual flood areas, but over hundreds of square miles of inundated area the losses to agriculture were complete, including in many cases harvested crops, equipment, and buildings. Difficulty was experienced in protecting the Coastal Highway, in South Carolina, 25 miles from the normal channel of the Savannah River, while the lower Ogeechee River overflowed the same highway, in Georgia, for a distance of 3 miles. The loss of livestock over these flooded areas was undoubtedly very great, since the swampy nature of the country and its inaccessibility under storm conditions prevented precautionary measures.
>
> The industrial concerns along the river opposite Augusta experienced heavy losses, the brickyards being deeply submerged and frame buildings of all sizes being wrecked and carried away. Many of the houses in Hamburg, also opposite Augusta, were carried away and the negro occupants rendered homeless for the time being.
>
> Replacement of damaged parts of the Sandbar Ferry highway bridge below Augusta will cost $150,000, while two spans of the City Bridge, at Fifth Street, were swept away and a railroad bridge lost two massive steel spans. At the Thirteenth Street Bridge only the approach on the Carolina side was damaged and the bridge was put back into use promptly.
>
> Losses in Augusta were due to storm damage and the effect of the backwater. Many streets in the hill section were badly torn up, while breaks of considerable length occurred in the banks of the city power canal.
>
> Total damage in the city and to city property was probably about $275,000. County roads and bridges, including Sandbar Ferry, suffered to the extent of $500,000, while the loss to the agricultural interests in this, Richmond County has been placed at $175,000. Total damage in North Augusta and Hamburg is estimated at $200,000, while elsewhere in Aiken County storm and flood damage to public and private interests must have amounted to at least $400,000. In Columbia County, Ga., above Augusta, agriculture suffered a loss exceeding $200,000, and roads and bridges were undoubtedly damaged to a like extent. Losses in Georgia and South Carolina in counties contiguous to the Savannah River must have aggregated in the neighborhood of $5,000,000 to public, corporation, and private property. This may reasonably be considered a low estimate.

The value of property saved through Weather Bureau warnings is roughly estimated at $1,000,000.

To the north and south of the Savannah, the floods in the Santee and Altamaha systems and in the rivers of North Carolina were the only ones of importance. Along the Santee and Altamaha the rain causing the rises occurred, as in the Savannah drainage area, in two falls—the first on September 26–27 and the second during and immediately following September 30. The rises resulting from the first fall had not, of course, had time to recede when the second occurred; so that crests considerably above flood stages were reached in both systems. Losses in the Altamaha Basin are estimated to have reached $500,000, and those in the Santee $1,097,330, distributed as follows:

Tangible property	$894, 850
Matured crops	82, 980
Prospective crops	100, 400
Livestock	2, 575
Suspension of business	16, 525
Value of property saved by warnings	160, 315

The distribution of flood losses comprised the whole of the basins below Pelzer and Gaston Shoals, S. C., and Mount Holly, N. C., but the region along the Santee and west of the Catawba-Wateree suffered the major portion of the losses.

The Cape Fear River flood and those in the Neuse and Tar Rivers of North Carolina are reported upon by the official in charge of the Weather Bureau office at Raleigh, N. C., as follows:

> The Cape Fear flood was the third heaviest of record; it was slightly less so than the flood of last year at Fayetteville and Elizabethtown, but heavier at Moncure, the rainfall being heaviest in the drainage area above Moncure and falling off sharply toward

the coast. The flood in the Neuse reached 0.2 foot above the high-water mark at Smithfield on the 4th, but was a foot under the high record at Neuse, N. C., and was reported about 18 inches below the high mark in the lower portion at Kinston. The rainfall was the heaviest in the middle watershed, the amount at Raleigh being the greatest of record for the length of time. Floods in the Tar and Roanoke were heavy, but not close to record floods.

Warnings were of much value to many interests, especially in the middle and lower portions of the rivers. Damage was not nearly as heavy as during the floods of last year for two reasons: First, the overflow occurred later in the season when crops were practically matured and partly harvested or ready to be harvested; second, less rain occurred in the lower sections, and with clear weather following the rain for a week or more there was ample time to move crops, stock, and other property to places of safety. One instance may be mentioned, for example, where a farmer in Wayne County employed 100 hands and 40 wagons or trucks and harvested his entire crop on 2,000 acres of land in advance of the flood.

The rise in the Cape Fear at Fayetteville from 5 feet at 8 a. m. of October 1 to 46 feet at 8 a. m. of October 2, 41 feet in 24 hours, is a record change for this district. One instance is mentioned here where by quick action one plant saved goods valued at $10,000. Losses sustained were as follows:

Tangible property	$200,000
Livestock, and matured and prospective crops	500,000
Suspension of business	100,000
Value of property saved by warnings	350,000

Other Atlantic and East Gulf drainage floods were moderate, or at worst not particularly serious. A loss of $30,000, of which $14,000 was in crops, occurred in the Pedee system of South Carolina (savings through flood warnings, $257,000); and damage to the extent of $36,500 was done on the Choctawhatchee River at Geneva, Ala., and Caryville, Fla. (savings through flood warnings, $3,000).

In the Ohio Valley rainfall was especially heavy over the Monongahela and lower Allegheny Basins; but, owing to the extreme dryness of the ground, and in some measures to the lowness of the streams themselves, the effectiveness of the rain was materially reduced and the floods of little consequence. The total loss was about $10,000.

No other damage is reported in the Ohio drainage basin except $5,000 to corn along the Kanawha River.

River and station	Flood stage	Above flood stages—dates From—	To—	Crest Stage	Date
ATLANTIC DRAINAGE					
	Feet			*Feet*	
Schuylkill: Reading, Pa	10	2	2	10.0	2
James: Columbia, Va	18	3	3	18.0	3
Roanoke:					
Randolph, Va	21	3		28.8	4
Weldon, N. C	30	2	8	45.6	6
Dan:					
Danville, Va	8	2	4	11.6	3
Clarksville, Va	12	3	5	15.1	5
Tar:					
Rocky Mount, N. C	9	1	7	13.0	3
		22	26	13.4	23
Tarboro, N. C	18	3	11	26.6	7
		24	30	25.5	27
Greenville, N. C	14	4	12	19.7	8-9
		25	31	18.8	29
Fishing Creek: Enfield, N. C	15	3	5	16.3	4
		23	25	16.2	24
Neuse:					
Neuse, N. C	15	1	8	23.7	4
		22	22	16.0	22
Smithfield, N. C	14	1	10	26.5	3
		22	24	18.5	23
Cape Fear:					
Fayetteville, N. C	35	2	7	64.1	4
Elizabethtown, N. C	22	2	10	38.9	6
Haw: Moncure, N. C	22	1	4	33.0	2
Peedee:					
Cheraw, S. C	27	2	6	39.8	4
Mars Bluff, S. C	17	3	14	27.3	7
Poston, S. C	18	6	17	26.5	10
Lynches: Effingham, S. C	14	6	10	19.4	7
Santee:					
Rimini, S. C	1	2	(1)	31.8	6
Ferguson, S. C	12	1	(2)	21.0	7
Jamestown, S. C	12	7		29.1	11-12
Catawba:					
Mount Holly, N. C	15	2	3	19.0	3
Catawba, S. C	12	2	4	28.7	3
Wateree:					
Camden, S. C	24	2	5	36.0	3
Malta, S. C	14	4	7	18.0	6
Congaree: Columbia, S. C	15	2	6	33.1	3
Broad: Blairs, S. C	15	1	5	39.5	3
Saluda:					
Pelzer, S. C	7	1	4	11.6	2
		22	23	8.6	22
Chappells, S. C	14	(1)	6	30.7	2
		23	24	17.9	24
Savannah:					
Calhoun Falls, S. C	6	1	3	10.1	2
Augusta, Ga	32	1	4	45.1	2-3
Broad: Carlton, Ga	11	1	3	27.0	2
Altamaha:					
Charlotte, Ga	15	(1)	17	25.2	9-10
Doctortown, Ga	10	2	16	11.2	12-13
Everett City, Ga	10	(1)	23	15.1	14
Oconee:					
Milledgeville, Ga	22	1	5	37.0	2
Dublin, Ga	22	3	9	27.6	5
Ocmulgee:					
Macon, Ga	18	1	4	25.1	3
Hawkinsville, Ga	25	4	8	30.6	6
Abbeville, Ga	11	2	13	17.4	8
Lumber City, Ga	15	4	14	20.0	10-11
EAST GULF DRAINAGE					
Apalachicola:					
River Junction, Fla	20	4	6	21.4	5
Blountstown, Fla	20	4	9	21.9	6
Flint:					
Montezuma, Ga	20	4	5	20.3	4
Albany, Ga	20	3	10	25.3	5
Chattahoochee:					
Eufaula, Ala	40	2	3	47.0	2
Alaga, Ala	30	2	4	39.1	3
Choctawhatchee:					
Geneva, Ala	23	2	5	[3] 26.9	3
Caryville, Fla	12	2	9	14.9	4
MISSISSIPPI DRAINAGE					
Tygarts: Philippi, W. Va	20	3	3	22.0	3
Monongahela:					
Lock No. 15, Hoult, W. Va	22	3	3	25.0	3
Lock No. 7, Greensboro, Pa	30	3	3	36.5	3
Lock No. 4, Pennsylvania	31	3	4	35.4	3
McKeesport, Pa	16	3	3	16.2	3
Little Kanawha: Glenville, W. Va	23	3	3	23.9	3
New:					
Ivanhoe, Va	15	2	2	20.0	2
Radford, Va	14	2	2	18.5	2
Glenlyn, Va	11	3	3	14.8	3
Elk: Clay, W. Va	18	3	3	23.0	3
Scioto: Larue, Ohio	11	23	24	11.4	24
French Broad: Asheville, N C	4	1	3	6.0	2
		22	22	4.8	22
Big Pigeon: Newport, Tenn	6	2	2	7.6	2
Nolichucky: Embreeville, Tenn	10	22	22	10.6	22

[1] Continued from last month. [2] Continued at end of month. [3] Estimated.

THE EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, OCTOBER, 1929

By J. B. KINCER

General summary.—The first decade was generally favorable for seasonal farm work, although there was some delay by heavy rains in the Atlantic States and a few interior sections. In parts of the central and southwestern winter-wheat belt rain was needed, but the soil was in rather favorable condition over much of the country. There was no material frost damage and, while late fall crops matured rather slowly due to cool weather, fair progress was made.

During the second decade dry, sunny weather in the Southeast made favorable conditions for crops and field work, while generous rains in some of the dry sections of the winter-wheat belt were very beneficial, although more moisture was needed locally in the Lake region.

The Pacific Northwest continued very dry. There was some heavy frost reported in middle Atlantic sections, but no material harm occurred.

In contrast to the preceding weather, that during the last decade brought rather general frost over much of the interior of the country, with light deposits in exposed places as far south as the northern portions of Louisiana and Florida. Tender vegetation was frosted and some cotton tops were nipped in parts of the western belt, but crops were so far advanced that there was only slight injury. It was also less favorable for field work in much of the interior, but in the Southwest and middle Gulf sections rainfall was beneficial; drought was still unrelieved at the close of the month in the interior of the Pacific Northwest.

Small grains.—During the first decade early-sown winter wheat did well in the Southwest, but it was too dry for much plowing or planting. Seeding was well advanced in most of the Great Plains, but the soil had just become moist enough for this work in Missouri. In parts of the Ohio Valley it was too dry for planting, but in other areas this work was well along, with the early crop up to good stands locally. The weather favored plowing and planting in the northern Great Plains and the Northwest, but the interior of the Pacific Northwest continued very dry, with moisture needed to condition the soil. During the second decade there were beneficial rains in the southwestern belt, extending into Missouri, but parts of this area were still dry; elsewhere conditions were favorable for the winter-wheat crop. During the last decade there was a continuation of favorable conditions and the general advance of the crop was good to excellent, with ample soil moisture. The Pacific Northwest continued seriously dry and seeding was delayed, with the early sown uneven and much in need of reseeding.

Corn.—The favorable mild, open weather during the month permitted late corn to mature in good shape. In some interior sections, especially in Missouri, extreme southern Iowa, and the southern half of Illinois, much corn had been in precarious condition, because of the possibility of harm from frost, but the bulk matured satisfactorily and at the close of the month the crop was practically all safe. There was some delay to husking and picking by rain, but this work, in general, advanced rapidly, with unusually favorable weather for the use of husking machines in Iowa during the last decade.

Cotton.—During the first decade there was some interruption by rain to cotton picking and ginning in Arkansas, but generally good progress was made in this work. Bolls opened fast in Oklahoma, while in western Texas the warm weather favored maturity of late bolls. In central parts of the belt there was fair advance made in gathering the crop, but in eastern sections excessive rainfall, with consequent flooding of bottom lands, was decidedly unfavorable and there were many reports of rotting bolls and damaged staple. There were heavy rains in the northwestern belt during the second decade, with interruption to picking and some damage, but the latter part was favorable and gathering continued, although largely completed in Texas, except in the west and northwest. Fair weather in the southeast favored drying, but in the northeastern belt there were some further heavy rains. During the last decade there was some injury to cotton tops by frost in the western belt, with growth generally stopped in the northwest, but no widespread damage, and the frost promoted rapid opening of bolls. In Oklahoma picking was further advanced than in an average year and this work was completed in much of Arkansas.

Miscellaneous crops.—Pastures and meadows were in fair to good condition in most sections east of the Rocky Mountains and ranges were good and affording some feed in the northern Great Plains. Rain or snow was beneficial in the Northwest, while generally good condition was reported from the Southwest. The unfavorably dry conditions in the far western States caused a shortage of range feed and stock water. Livestock were largely on winter ranges at the close of the month.

Potato digging was mostly completed at the close of the month and, while there was some injury to truck reported, condition of this crop was good, although growth was confined mainly to the winter producing areas. Sugar beet digging was largely favored, as were cane grinding and cutting. Citrus continued in generally satisfactory condition.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

Judging from the number of days in which gales were reported, the weather during the month would not be considered severe over the ocean as a whole, except in the vicinity of the coast of southern Europe where the number of gales was somewhat above the normal. There were, however, a number of unusual features that will be referred to later. These include the anticyclonic gales on the 11th, the severe disturbance in southern waters on the 21st and 22d, and the disturbances of tropical origin in the first and last decades of the month.

Fog was reported on from 10 to 13 days over the Grand Banks; on from 4 to 6 days along the American coast, and on from 1 to 6 days over the steamer lanes, while the coast of Europe was comparatively clear.

Charts VIII and IX show the conditions on the 1st and 2d, respectively, and used in connection with Charts VIII to XV for September give an idea of the track and extent of the tropical distrubance that was first reported on September 22, while Chart VIII for that month gives its position on the 23d. On October 3 the center of this disturbance was near Albany, N. Y., and on the 4th near Father Point, Quebec, where a barometric reading of 29.32 inches was reported. At Belle Isle on that date, the morning observation gave the wind as east, force 9, barometer 29.52 inches. Vessels between the fortieth parallel and Newfoundland encountered southerly to southwesterly winds of force 5 to 8. By the 5th this LOW had apparently begun to fill in, the barometer at Belle Isle on that day reading 29.66 inches, while moderate westerly gales continued between the fortieth and forty-fifth parallels, west of the sixtieth meridian.

On the 5th a depression was over Ireland, afterwards developing into a severe disturbance, and from that date until the 8th moderate to strong gales were prevalent over the eastern section of the steamer lanes, the storm area on the 7th extending as far west as the thirty-fifth meridian.

On the 10th and 11th very unusual conditions existed over the western section of the ocean. There was a pronounced HIGH over the eastern United States, with crest near New York City, and practically normal pressure over the Caribbean Sea. The 8 a. m. barometer reading

at New York was 30.72 inches on the 10th and 30.68 inches on the 11th, and the remarkably steep gradient resulted in moderate to strong northeasterly gales along the coast from Key West to Hatteras, accompanied by comparatively high barometric readings. A number of press accounts of this storm have been received and the consensus of opinion of different shipmasters and officers was that the conditions were most unusual, as an increasing wind on a rising barometer is not often experienced. Capt. Chester W. Gilbert of the American steamship *Venezuela* was quoted as having stated that he had only seen one other storm of this character in his whole career at sea.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian). North Atlantic Ocean October, 1929.*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	*Inches*
Belle Isle, Newfoundland	29.81	[1] −0.06	30.36	31st	28.82	29th.
Halifax, Nova Scotia	30.01	[2] −0.03	30.58	30th	29.28	17th.
Nantucket	30.03	[2] −0.05	30.60	10th	29.36	17th.
Hatteras	30.06	[2] −0.04	30.52	10th [3]	29.50	2d.
Key West	29.95	[2] −0.01	30.08	26th	29.70	21st.
New Orleans	30.04	[2] −0.02	30.22	24th	29.72	28th.
Cape Gracias, Nicaragua	29.84	[1] −0.08	29.92	27th	29.76	18th.
Turks Island	29.99	[2] +0.04	30.08	5th [4]	29.90	30th.
Bermuda	30.07	[2] 0.00	30.30	31st	29.76	16th.
Horta, Azores	30.27	[1] +0.14	30.44	10th [3]	29.92	24th.
Lerwick, Shetland Islands	29.47	[1] −0.32	30.33	31st	28.72	2d.
Valencia, Ireland	29.86	[1] −0.05	30.39	31st	29.20	5th. [3]
London	29.84	[1] −0.07	30.38	31st	29.13	6th.

[1] From normals shown on Hydrographic Office Pilot Chart, based on observations at Greenwich mean noon, or 7 a. m. seventy-fifth meridian time.
[2] From normals based on 8 a. m. observations.
[3] And on other date.

Results for Julianehaab, Greenland, are not given, as observations were missing from that station on 7 days.

From the 11th to 14th a depression over the central section of the ocean was responsible for moderate to strong gales during the greater part of that period, and on the 13th and 14th winds of force 7 to 10 were reported from the area between the fortieth and fiftieth parallels and the thirtieth and fiftieth meridians.

On the 15th anticyclonic northerly winds of gale force were encountered by vessels between the thirtieth and thirty-sixth parallels and the thirty-fifth and forty-second meridians, accompanied by barometric readings of from 30.11 to 30.20 inches.

On the 16th and 17th a LOW was off the American coast between Nantucket and Belle Isle, with moderate to strong gales prevailing on both days.

From the 19th to the 22d the region between the Bermudas and Azores was swept by a severe disturbance, the wind reaching hurricane force at times. Charts X and XI show the conditions on the 21st and 22d, respectively. On the 21st and 22d there was also a disturbance of tropical origin off the American coast between the twenty-fifth and thirty-fifth parallels.

From the 23d to 27th westerly to southwesterly gales were encountered by vessels in the middle and eastern sections of the steamer lanes.

On the 28th one LOW was central near Cape Ray, Newfoundland, and a second near 58° N., 28° W.; these both developed into severe disturbances as they moved slowly eastward, and on the 29th gales of force 8 to 11 were encountered between Halifax and Belle Isle, west of the forty-fifth meridian, and on the same day winds of force 8 and 9 prevailed between the twentieth meridian and British coast. On the 30th there was an extensive storm area over the middle section of the ocean, while by the 31st moderate weather prevailed generally.

OCEAN GALES AND STORMS, OCTOBER, 1929

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Naperian, Br. S. S.	Savannah	Liverpool	32 10 N.	80 05 W.	Oct. 1	10 a., 1	Oct. 3	29.54	SE.	SE., 8	SW.	—, 8	SSE.-SW.
Balsam, Am. S. S.	New York	Glasgow	55 27 N.	7 45 W.	1	11 p., 1	2	29.08	S.	SW., 7	W.	S., 10	S.-W.
New York, Am. S. S.	Port Arthur	New York	33 38 N.	76 15 W.	2	1 a., 2	3	29.61	SE.	SSE., 8	W.	SW., 9	
Helen, Am. S. S.	San Juan	Philadelphia	36 50 N.	74 17 W.	3	8 a., 3	3	29.61	W.	W., 10	NW.	W., 10	NW.-W.
New York City, Br. S. S.	Bristol	do	44 00 N.	63 00 W.	4	6 a., 4	4	29.48	SW.	SW., —	SW.	—, 9	Steady.
West Hobomac, Am. S. S.	Newcastle	New Orleans	48 51 N.	7 16 W.	5	5 p., 5	5	29.30	WSW.	NW., 8	NW.	NNW., 10	SW.-NW.
Tuscaloosa City, Am. S. S.	Canal Zone	Liverpool	50 16 N.	11 31 W.	5	4 a., 6	6	29.45	NW.	NW., 10	NW.	NW., 11	NW.-WNW.
Coldwater, Am. S. S.	Savannah	Bremen	49 18 N.	17 15 W.	5	8 p., 7	9	29.22	SE.	W., 9	NW.	—, 9	SSW.-NNE.
Winnebago, Br. S. S.	Brixham	New York	48 04 N.	42 20 W.	8	Noon, 9	9	29.81	SSW.	SW., 9	W.	SW., 9	SW.-W.
Wm. G. Warden, Am. S. S.	Corpus Christi.	do	26 53 N.	79 43 W.	10	—, 10	12	30.06	NE.	NE., 9	E.	ENE., 9	NE.-E.
McKeesport, Am. S. S.	Havre	do	51 03 N.	32 23 W.	10	5 p., 11	11	29.64	SW.	SSW., 8	SSW.	SW., 9	SW.-SSW.
Tynefield, Br. M. S.	Belfast	Baton Rouge	42 12 N.	47 37 W.	9	8 p., 12	14	29.77	NE.	NNE., 6	N.	NE., 10	NNE.-NE.
Milwaukee, Ger. M. S.	Cobh	New York	49 10 N.	31 40 W.	14	8 a., 14	14	29.73	NNW.	NNW., 10	W.	—, 10	NNW.-W.
Excelsior, Am. S. S.	Marseille	Boston	42 38 N.	63 10 W.	16	7 a., 16	16	29.45	SE.	SE., 10	W.	SE., 10	SE.-W.-NW.
Inverglass, Br. S. S.	Las Piedras	Southampton	30 55 N.	46 31 W.	17	Mdt., 17	18	29.74	N.	WSW., —	SSE.	WSW., 9	
Exton, Am. S. S.	New York	Genoa	39 56 N.	73 55 W.	20	9 a., 20	24	29.98	NE.	NE., 7	NE.	S., 10	S.-NE.
Liberty Glo, Am. S. S.	Bremen	Jacksonville	48 48 N.	7 30 W.	20	2 p., 20	21	29.49	WNW.	NW., —	—	N., 9	WNW.-NNW.
Momus, Am. S. S.	New York	New Orleans	31 20 N.	76 50 W.	21	2 p., 21	21	29.67	ESE.	SE., 9	SE.	SE., 10	Steady.
Magmeric, Am. S. S.	Antwerp	Charleston	36 00 N.	46 00 W.	21	7 p., 21	21	29.43	SE.	SE., —	W.	—, 11	
Deer Lodge, Am. S. S.	English Channel.	Gulf of Mexico	35 06 N	43 41 W.	21	4 p., 21	21	29.72	ESE.	SSE., 9	SSW.	S., 12	
Steel Seafarer, Am. S. S.	Port Said	New York	36 30 N.	1 40 W.	20	11 p., 21	22	29.55	WSW.	SW., 8	W.	SW., 9	SW.-W.
San Gil, Br. S. S.	St. John, N.B.	Habana	32 17 N.	75 30 W.	21	3 a., 22	22	29.55	SE.	SE., 10	W.	SE., 10	Steady.
Wieldrecht, Du. S. S.	Antwerp	New Orleans	46 13 N.	12 43 W.	25	11 p., 25	26	29.88	NNW.	NNW., 10	NW.	NNW., 10	
Tuscaloosa City, Am. S. S.	London	Baltimore	48 34 N.	44 07 W.	20	3 p., 26	30	29.37	NNW.	S., 10	N.	WNW., 10	SSW.-S.
West Alseek, Am. S. S.	Avonmouth	New York	50 45 N.	16 05 W.	28	2 p., 28	29	29.62	WSW.	W., 8	NW.	WNW., 10	WSW.-WNW.
President Roosevelt	United Kingdom.	do	47 45 N.	40 30 W.	29	6 p., 29	30	29.59	SSW.	WSW., 8	WNW.	WSW., 9	SSW.-WSW.

Ocean gales and storms, October, 1929—Continued

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH PACIFIC OCEAN			° ′	° ′				*Inches*					
Pres. Taft, Am. S. S.	Yokohama	Seattle	49 40 N.	170 00 W.	1	8 p., 1	1	29.09	W	W., 7	SW	WSW., 9	SW.-NW.
Arabia Maru, Jap. S. S.	Victoria	Yokohama	52 25 N.	162 00 W.	1	3 p., 1	2	28.68	SSE	WSW., 9	NW	W., 9	
Admiral Rogers, Am. S. S.	Seattle	Alaska	56 50 N.	134 37 W.	1	4 p., 3	5	29.16	SE	SE., 8	SE	SE., 8	
San Pedro Maru, Jap. S. S.	San Francisco	Osaka	33 33 N.	148 50 E.	5	Mdt., 5	6	29.87	S	SSW., 8	WSW	SSW., 9	S.-SW.-WSW.
Grays Harbor, Am. S. S.	Puget Sound	Orient	44 00 N.	154 48 E.	5	Noon, 6	7	29.50	E	SW., 2	NNW	SE., 10	SW.-NW.
Arabia Maru, Jap. S. S.	Victoria	Yokohama	48 30 N.	167 25 E.	7	2 p., 7	7	29.62	ESE	E., 9	NE	E., 9	
Arizona Maru, Jap. S. S.	Yokohama	Victoria	50 57 N.	169 45 W.	7	8 a., 8	9	29.07	SE	W., 8	N	SE., 9	3 pts.
Lochkatrine, Br. M. S.	London	San Diego	13 48 N.	95 16 W.	8	4 a., 8	8	29.74	NNW	N., 7	E	N., 8	NNW.-NE.
Admiral Rogers, Am. S. S.	Alaska	Seattle	50 54 N.	127 40 W.	8	Noon, 8	8	29.46	E	E., 8		E., 8	
Emp. of France, Br. S. S.	Yokohama	Vancouver	50 34 N.	164 12 W.	8	4 p., 8	8	28.66	W	NE., 4	NE	WSW., 9	WSW.-NE.
Pennsylvania, Am. S. S.	Hong Kong	San Francisco	48 15 N.	167 36 W.	8	Noon, 8	9	29.16	W	W., 8	WNW	W., 10	W.-WNW.
Golden Star, Am. S. S.	do	do	23 14 N.	128 46 E.	8	1 p., 10	11	28.92	NNE	N. —.	NNW	NW., 12	
Ayaha Maru, Jap. S. S.	Grays Harbor	Yokohama	51 40 N.	166 40 E.	9	2 p., 9	10	28.89	SSE	NW, 12	N	NW., 12	W.-NW.-N.
Oregon, Am. S. S.	Shanghai	San Francisco	33 30 N.	137 40 E	9	Noon, 9	10	29.60	NE	NE., 7	NE	NE., 9	Steady.
Do	do	do	34 12 N.	140 37 E.	12	—, 12	14	29.60	NE	NE., 7	N	NE., 10	Steady.
Illinois, Am. S. S.	Hong Kong	do	46 16 N.	171 25 E.	11	Noon, 13	14	29.14	ESE	W., 8	NNW	ESE., 8	ESE.-W.
Steel Trader, Am. S. S.	Englewood, B. C.	Los Angeles	50 46 N.	128 32 W.	12	4 a., 12	13	29.75	SSE	SSE., 8	SSE	SSE., 8	Steady.
Choyo Maru, Jap. S. S.	Miike	Portland	49 10 N.	147 40 W.	16	8 a., 17	18	28.95	NE	NNE., 10	WNW	NNE., 10	NNE.-NNW.
Tokiwa Maru, Jap. S. S.	Vancouver	Yokohama	50 30 N.	176 32 W.	17	8 p., 18	20	28.59	NNE	WNW., 5	NW	—, 9	W.-WNW.-NW.
Chief Skidegate, Br. S. S.	Tacoma	do	49 04 N.	175 10 E.	18	Noon, 19	20	28.57	SW	W., 11	NW	W., 11	SW.-W.-WNW.
Mayebashi Maru, Jap. S. S.	Otaru	San Francisco	46 15 N.	169 40 E.	18	4 a., 19	21	29.53	SSE	WNW., 7	N	NW., 9	12 pts.
Havre Maru, Jap. S. S.	do	do	49 00 N.	152 00 W.	18	1 p., 20	22	28.71	S	S., 6	SSW	SE., 10	Steady.
Columbia Maru, Jap. M. S.	Kobe	Portland	49 30 N.	154 30 W.	19	1 a., 20	21	28.67	S	ESE., 6	S	S., 9	S.-SE.-S.
Maunalei, Am. S. S.	Manila	Honolulu	12 15 N.	127 00 E.	20	8 p., 21	22	29.37	WNW	W., 9	S	W., 9	WNW.-W.-SW.
Pres. Wilson, Am. S. S.	Balboa	San Pedro	14 00 N.	95 10 W.	21	2 a., 22	22	29.77	NNW	N., 8	NE	N., 8	NNW.-N.-NE.
Hakushika Maru, Jap. S. S.	Miike	Victoria	42 35 N.	155 05 E.	21	2 p., 22	23	29.03	SW	W., 11	NNW	W., 11	WSW.-NNW.
Admiral Evans, Am. S. S.	Seattle	Kodiak	57 55 N.	152 32 W.	23	Noon, 24	24	28.67	SE	NE., 8	SW	NE., 8	NE.-SW.
Emp. of Russia, Br. S. S.	Yokohama	Victoria	50 45 N.	151 04 W.	23	6 p., 23	24	28.46	ENE	SSE., 5	SW	SW., 9	S.-SSE.-S.
Shikisan Maru, Jap. S. S.	do	San Francisco	45 28 N.	147 00 W.	22	2 p., 23	24	29.29	S	SSW., 9	W	S., 10	S.-SW.-W.
Pres. Jackson, Am. S. S.	Honolulu	Yokohama	35 00 N.	140 25 E.	25	Mdt., 26	27	29.00	E	S., 9	SW	S., 9	Steady.
Iowa, Am. S. S.	Japan	San Francisco	45 22 N.	169 05 E.	25	6 a., 27	28	29.86	NW	NW., 9	NW	NW., 9	Steady.
Java, Nor. M. S.	San Pedro	Yokohama	36 07 N.	141 54 E.	26	5 a., 27	27	29.40	SSW	SSW., 12	NNE	SSW., 12	
Golden Star, Am. S. S.	Hong Kong	San Francisco	42 07 N.	160 29 W.	26	5 p., 26	27	28.66	NE	Calm	SSW	WNW., 11	ENE.-0-WNW.
Oregon, Am. S. S.	Shanghai	do	46 30 N.	152 41 W.	26	7 p., 26	28	29.43	SE	SSE., 10	S	SSE., 10	Steady.
William Penn, Am. M. S.	Hong Kong	Kobe	26 00 N.	122 20 E.	26	—, 27	28	30.14	NE	NE., 8	NE	NE., 8	Steady.
Satanta, Br. S. S.	Hankow	San Pedro	37 12 N.	150 54 E.	26	2 p., 27	28	29.48	S	S., 9	N	S., 9	S.-WNW.
Tamaha, Br. S. S.	Nagasaki	do	38 00 N.	174 27 W.	27	6 p., 28	29	29.10	SE	SW., 8	NW	SSE., 10	SSE.-SW.
San Pedro Maru, Jap. S. S.	Moji	San Francisco	35 35 N.	177 10 W.	28	4 p., 28	29	29.41	S	WSW., 8	NW	SW., 9	WSW.-W.-NW.
Hakushika Maru, Jap. S. S.	Miike	Victoria	49 58 N.	161 08 W.	29	4 a., 30	Nov. 1	28.49	NNE	W., 5	SW	SW., 11	SE.-SW.
SOUTH PACIFIC OCEAN													
James McGee, Am. S. S.	Buenos Aires	Talara	51 25 S.	76 41 W.	11	11 p., 11	12	28.98	NNW	NNW., 8	WSW	NW., 10	

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Pronounced winter conditions of atmospheric pressure prevailed over the Aleutian Islands and the Gulf of Alaska in October. At St. Paul, in the Bering Sea, pressure had risen slightly since September. At Dutch Harbor there had been a slight fall, from an average of 29.51 to 29.44 inches, but at Kodiak the fall from September to October had amounted to 0.59 inch, or a drop from 29.85 to 29.26 inches, the maximum daily reading for the latter month being 29.90. At Juneau the downward change was 0.37 inch, or from 30.12 to 29.75. The Aleutian cyclone, strongly developed, was thus central over the northwestern waters of the Gulf of Alaska, in its fluctuations being much more frequently situated east than west of the Alaska Peninsula.

The California-Pacific anticyclone in the early days of the month overspread much of middle and higher latitudes. During the second and third weeks it was subject to strong cyclonic displacements from the northward, but the final week showed some recovery. On the average it extended from the Washington, Oregon, and upper California coasts southwestward to middle latitudes, below the fortieth parallel, and thence westward in a comparatively narrow and irregular region to approximately the one hundred and sixtieth meridian of east longitude. As a whole it was apparently less well developed than in any previous month of the year.

Barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean, are given in the following table:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, October, 1929*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1] [2]	29.65		30.12	28th	29.14	16th.
Dutch Harbor [1] [3]	29.44	−0.25	30.14	7th	28.82	19th.
St. Paul [1] [3]	29.60	−0.06	30.24	7th	29.18	1st.
Kodiak [1]	29.26	−0.33	29.90	27th	28.36	10th.
Midway Island [1]	30.07	+0.02	30.22	31st	29.86	22d.
Honolulu [4]	29.99	−0.01	30.07	7th	29.83	20th.
Juneau [4]	29.75	−0.12	30.36	6th	29.19	15th.
Tatoosh Island [4] [5]	30.07	+0.04	30.38	31st	29.64	16th.
San Francisco [4] [5]	29.99	−0.01	30.14	11th	29.84	28th.
San Diego [4] [5]	29.92	−0.01	30.02	31st	29.66	28th.

[1] P. m. observations only.
[2] For 29 days.
[3] For 30 days.
[4] A. m. amd p. m. observations.
[5] Corrected to 24-hour mean.

With the great activity of the Aleutian cyclone and the increasing number of lows entering the upper Pacific from Asia, trans-Pacific steamships experienced rougher weather generally than during any month since February or March. On the northern routes, between longitudes 155° W. and 160° E., gales were reported on 15 to 30 per cent of the days. Many of these were of force 10, and full storm winds were reported on the 19th near 49° N., 175° E.; on the 22d, near 43° N., 155° E.; on the 26th, near 42° N., 160° W.; and on the 31st, near 51° N., 156° W. In addition, hurricane velocities occurred on the 9th near 51° N., 167° E. Along the American coast gales were reported off California on the 28th; off Vancouver Island on the 8th and 12th; and in Alaskan waters on the 4th, 9th, 23d, and 31st. One of the most interesting storm developments of the month was that which appeared as a slight depression near Midway Island on the 25th. It apparently joined with another depression from the northwest on the 26th and rapidly deepened into an intense storm, at which time it was experienced by the American steamship *Golden Star*, Capt. O. Lee, Hong Kong to San Francisco. The observer, Mr. P. A. Caldwell, reported that "at 4 p. m. wind hauled to ENE., force 8, barometer 28.70, wind gradually decreasing. Between 5 and 6 p. m. wind was calm. Lowest barometer reading at this time was 28.66; then at about 6 p. m. wind hauled to NNW., 6–8. Engines put on half speed account of heavy seas. At 8 p. m. wind increased to force 11." This is one of the few instances we have of seamen reporting a calm in the center of an extratropical cyclone.

Of the typhoons mentioned by the Rev. José Coronas in the subjoined article, reports from our marine observers show that several vessels were more or less heavily involved in two or more of these tropical storms. The following may be mentioned because of the higher winds encountered:

The American steamship *Golden Star*, Hong Kong to San Francisco, ran into northeasterly gales of force 8 on the 8th near 23° N., 124° E. On the 9th the wind hauled into north and increased to force 9. On the 10th, near 23° N., 129° E., immediately to the westward of the typhoon center, the vessel experienced hurricane velocities from the northwest, lowest pressure 28.92. These continued from 4 a. m. until noon, after which there was a slow moderation.

The Japanese steamship *Ishin Maru*, Capt. G. Yoshihira, second officer and observer, Mr. N. Obori, Miike to Astoria, in a special report to the Hydrographic Office, is shown to have encountered hurricane winds generally from midnight of the 25th until noon of the 26th, her noon position being in 32° 23′ N., 134° 29′ E., lowest pressure 29.10 inches, from 10 to 11 a. m., between which hours she was becalmed in the "eye" for 30 minutes. She entered the storm area on the 25th, with gales ranging in force from 8 to 11, and left it on the evening of the 26th.

The Norwegian motor ship *Java*, San Pedro to Yokohama, furnished a special report, with drawings, of her experience in the Japanese typhoon of the 26th–27th. On the 26th she ran into whole gales from south-southwest in about 36° N., 142° E. At 2 a. m. of the 27th the hurricane was at its height, barometer down to 29.40. The wind continued at force 12 until 10 a. m., after which it began to moderate. The observer calculated the radius of the typhoon to be 200 miles and the speed between 15 and 20 nautical miles an hour.

On account of the increasing number of continental anticyclones advancing upon the China coast, the northeast monsoon was strong on several days, particularly in the Taiwan Channel and northward therefrom. It was at times accentuated by the northerly winds of the tropical storms passing by to the eastward.

No cyclones appear to have formed in Mexican waters, but on several days, including the 4th, 8th, 12th, 22d, and 24th, moderate to fresh northers were encountered by vessels in and south of the Gulf of Tehuantepec.

The prevailing wind at Honolulu was from the east, and the next most frequent was from the northeast. The maximum velocity was at the rate of 22 miles an hour from the east on the 5th.

Although fog is comparatively infrequent on the open North Pacific during October, it formed on fewer days than usual this month, and was absent, according to available reports, except on the 7th and 9th, to the westward of longitude 150° W. Between that meridian and longitude 130° W. it was observed on a few days toward the end of the month, but along the coast of the United States from 20 to 30 per cent of the days had fog off Washington and Oregon and nearly 50 per cent had fog within 200 miles or less of San Francisco. Below Point Conception the percentage decreased rapidly to Point Eugenia, Lower California, where fog ceased. On the 13th the Canadian liner *Empress of Canada* grounded in Homer Bay, Straits of Juan de Fuca, during a dense fog, and was not floated until the 15th. Her passengers meanwhile were transferred safely to another steamship, the *Otter*, and landed at Victoria.

TYPHOONS AND DEPRESSIONS—FIVE DEPRESSIONS OR TYPHOONS OVER THE FAR EAST IN OCTOBER, 1929

By Rev. José Coronas, S. J.

[Weather Bureau, Manila, P. I.]

There were three very well developed and severe typhoons and two others of less importance over the Far East during the last month of October. None of them, however, touched the Philippines, but four remained in the Pacific and one entered Indo-China.

The first of the Pacific typhoons appeared on our weather map at 6 a. m. of the 4th near 145° longitude E. and 10° latitude N. It moved northwest on the 4th, and at 6 a. m. of the 5th it began to move W. or W. by N., threatening the Philippines; but in the afternoon of the 7th and during the 8th it turned to the NW. and N. On the 11th it recurved to ENE. near the northern Loochoos, and then it filled up soon on the 12th to the south of Japan.

The approximate position of the center at 6 a. m. of the period October 4 to 12 was as follows:

October 4, 6 a. m., 144° 45′ longitude E., 9° 45′ latitude N.
October 5, 6 a. m., 141° 20′ longitude E., 12° 50′ latitude N.
October 6, 6 a. m., 138° 50′ longitude E., 13° 10′ latitude N.
October 7, 6 a. m., 134° 35′ longitude E., 13° 35′ latitude N.
October 8, 6 a. m., 131° 10′ longitude E., 15° 10′ latitude N.
October 9, 6 a. m., 130° longitude E., 18° latitude N.
October 10, 6 a. m., 129° 25′ longitude E., 24° 10′ latitude N.
October 11, 6 a. m., 130° longitude E., 27° latitude N.
October 12, 6 a. m., 137° 10′ longitude E., 29° 30′ latitude N.

The second Pacific typhoon was rather small and apparently of no great intensity. It formed probably on the 13th far to the east of San Bernardino Strait near 132° longitude E., 12° latitude N. It moved NW. on the 13th and 14th and N. by W. on the 15th and 16th, filling up probably in the evening or night of the 16th to the east of southern Formosa.

The other two Pacific typhoons existed simultaneously for about four days, after which one of the two dis-

appeared or was absorbed by the other. A typhoon center was shown by our weather maps of the 14th to 15th as forming to the SSE. of Guam near 146° or 147° longitude E. and 8° or 9° latitude N. It moved northwestward from the 16th to the 18th, but inclined westward on the 19th.

On the 18th the other typhoon center appeared on our weather map of 6 a. m. near 130° longitude E. and 15° latitude N. It followed a very abnormal track at the beginning, making a complete loop to the east of southern Luzon from the 18th to the 22d. After the 22d the typhoon took a decided direction to the NNE. and NE. The center passed near the northern Loochoos at noon of the 25th and near the southeastern coast of Japan during the night of the 26th to 27th.

The two typhoon centers were clearly shown in our weather maps on the 18th to 21st; but on the 22d only one center could be distinguished. The approximate positions of the two centers at 6 a. m. from October 15 to 27 were as follows:

First typhoon:
October 15, 6 a. m., 146° 30′ longitude E., 8° 25′ latitude N.
October 16, 6 a. m., 145° longitude E., 9° latitude N.
October 17, 6 a. m., 142° 05′ longitude E., 10° 50′ latitude N.
October 18, 6 a. m., 140° 20′ longitude E., 12° 30′ latitude N.
October 19, 6 a. m., 140° longitude E., 14° 35′ latitude N.
October 20, 6 a. m., 136° 30′ longitude E., 16° latitude N.
October 21, 6 a. m., 134° 15′ longitude E., 15° 25′ latitude N.

Second typhoon:
October 18, 6 a. m., 130° longitude E., 15° latitude N.
October 19, 6 a. m., 127° 50′ longitude E., 13° 20′ latitude N.
October 20, 6 a. m., 128° 45′ longitude E., 14° latitude N.
October 21, 6 a. m., 128° 40′ longitude E., 15° latitude N.
October 22, 6 a. m., 127° 50′ longitude E., 15° 50′ latitude N.
October 23, 6 a. m., 127° longitude E., 18° latitude N.
October 24, 6 a. m., 128° 30′ longitude E., 21° 50′ latitude N.
October 25, 6 a. m., 130° longitude E., 26° latitude N.
October 26, 6 a. m., 135° longitude E., 31° 10′ latitude N.
October 27, 6 a. m., 145° longitude E., 37° latitude N.

On the 9th a small depression or typhoon of apparently little importance was shown on our weather maps over the western part of the China Sea not far from Indo-China. The center entered Indo-China in the early morning of the 10th moving westward.

CLIMATOLOGICAL TABLES [1]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, October, 1929

Section	Temperature							Precipitation					
			Monthly extremes							Greatest monthly		Least monthly	
	Section average	Departure from the normal	Station	Highest	Date	Station	Lowest	Date	Section average	Departure from the normal	Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	63.1	−1.3	4 stations	89	[2]7	2 stations	30	[2]23	5.10	+2.48	Union Springs	10.52	Millry	1.42
Arizona	64.0	+1.3	2 stations	109	6	Alpine	−1	29	0.42	−0.46	Pinedale	1.85	18 stations	0.00
Arkansas	62.2	0.0	Hope	93	17	Dutton	19	25	4.29	+1.32	Marshall	9.33	Paragould	1.11
California	62.2	+2.4	4 stations	108	5	Lake Sebrina	8	29	0.13	−1.09	Mount Shasta	1.90	70 stations	0.00
Colorado	46.8	+0.6	2 stations	90	[2]5	Lake Moraine	−5	30	1.25	+0.10	Peetz	3.56	Estes Park	0.08
Florida	71.7	−1.3	Brooksville	94	8	Cottage Hill	35	25	4.15	−0.2	Miami	20.18	2 stations	0.38
Georgia	63.5	−1.1	2 stations	90	[2]7	Blue Ridge	28	26	5.24	+2.48	Double Branches	11.97	Savannah	0.95
Idaho	48.4	+1.3	do	89	[2]1	Felt	−1	30	0.74	−0.65	Roland	2.61	Emmett	0.00
Illinois	54.2	−1.0	5 stations	85	15	3 stations	26	[2]5	3.39	+0.76	Hillsboro	6.05	Cairo	1.08
Indiana	52.7	−1.8	4 stations	84	16	2 stations	26	[2]18	3.83	+1.14	La Porte	8.67	Evansville	1.68
Iowa	51.8	0.0	Spencer	84	15	3 stations	23	25	3.10	+0.67	Bedford	6.55	Webster City	1.10
Kansas	57.2	+0.2	Richfield	91	5	Richfield	17	31	3.59	+1.62	Osage City	9.18	Richfield	T.
Kentucky	56.4	−1.8	3 stations	85	[2]16	Farmers	25	[2]18	3.65	+0.88	Jenkins	7.23	Middlesboro	1.30
Louisiana	68.3	+0.3	Lake Arthur	96	17	Tallulah	28	24	4.07	+0.77	Cinclare	12.39	Grand Cane	0.82
Maryland-Delaware	53.6	−2.7	Cambridge, Md	85	7	2 stations	23	[2]18	5.44	+2.58	Keedysville, Md	9.27	Princess Anne, Md	2.41
Michigan	47.5	−1.4	4 stations	80	15	5 stations	12	[2]9	3.67	+0.97	Morenci	6.02	Charlevoix	1.51
Minnesota	47.0	+1.3	Beardsley	89	6	Argyle	11	8	2.27	+0.44	Pigeon River Bridge	4.84	Winona	0.92
Mississippi	64.9	−0.3	2 stations	92	17	5 stations	30	[2]24	4.09	+1.40	Woodville	9.87	Meridian	1.82
Missouri	57.2	−0.2	Clinton	91	18	Neosho	23	25	5.54	+2.65	Marshall	8.58	Cape Girardeau	0.90
Montana	46.4	+2.1	2 stations	88	[2]2	2 stations	6	[2]24	0.86	−0.14	Adel	2.40	East Helena	0.24
Nebraska	52.1	+1.2	do	95	15	Sidney	2	29	3.07	+1.51	Auburn	9.16	Halsey	0.91
Nevada	53.4	+2.6	Las Vegas	101	6	Rye Patch	2	30	0.09	−0.55	Mahoney Ranger Station.	0.80	16 stations	0.00
New England	48.0	−1.5	2 stations	80	[2]20	Chelsea, Vt	14	11	2.93	−0.62	East Hartland, Conn.	6.71	Keene, N. H	1.38
New Jersey	52.3	−2.6	Indian Mills	80	20	Charlotteburg	17	11	4.61	+0.93	Charlotteburg	7.35	Cape May City	2.62
New Mexico	53.1	−0.2	Deming	97	2	2 stations	1	[2]23	1.20	+0.04	Lake Avalon	4.54	Park Springs Ranch	T.
New York	48.1	−1.7	5 stations	80	[2]20	Indian Lake	13	11	3.91	+0.69	Cortland	6.16	Mechanicville	1.61
North Carolina	58.1	−2.0	3 stations	87	1	Mount Mitchell	19	25	7.33	+4.28	2 stations	13.50	Manteo	1.26
North Dakota	46.8	+3.0	Steele	88	17	Steele	10	23	1.85	+0.85	Oakes	4.75	Max	0.28
Ohio	52.0	−1.9	2 stations	82	19	2 stations	24	18	4.18	+1.47	Marion	7.23	Willoughby	1.99
Oklahoma	62.5	+1.0	Hollis	95	6	Boise City	15	31	3.93	+0.65	Smithville	8.97	Kenton	0.35
Oregon	52.0	+1.9	Marshfield	99	22	Lake	7	29	0.97	−1.21	Cruzatte	3.41	2 stations	0.00
Pennsylvania	50.6	−1.8	Beaver Dam	85	19	Gouldsboro	14	11	5.59	+2.41	Welkert	10.40	Erie	1.65
South Carolina	61.1	−2.5	Beaufort (near)	88	5	Santuck	32	26	7.31	+4.27	Greenwood	12.69	Beaufort (near)	0.88
South Dakota	50.0	+1.3	4 stations	88	[2]5	Cottonwood	15	31	2.40	+1.00	Vivian	5.59	Deerfield	0.70
Tennessee	58.3	−1.2	2 stations	86	19	Rugby	22	26	3.75	+0.91	Erwin	7.83	Clinton	1.28
Texas	68.4	+0.9	3 stations	102	[2]2	Romero	17	25	2.55	−0.04	Austwell	7.26	Cotulla	0.14
Utah	50.8	+1.7	St. George	95	5	Panguitch	6	[2]24	0.65	−0.64	Hole-in-the-Rock Ranger Station.	2.66	Ibapah	0.00
Virginia	55.6	−1.8	2 stations	88	[2]2	3 stations	23	[2]9	6.91	+4.18	Columbia	11.75	Onley	3.62
Washington	51.3	+2.2	Kiona	89	15	Ruff	12	31	1.50	−1.80	Big Four	9.27	7 stations	T.
West Virginia	52.6	−2.4	Williamson	89	16	Pickens	21	18	6.17	+3.21	Harpers Ferry	10.93	Gary	3.92
Wisconsin	47.6	−0.3	High Falls	85	15	Prentice	9	22	2.02	−0.61	Brodhead	3.85	Rhinelander	0.84
Wyoming	44.5	+1.5	2 stations	85	[2]5	South Pass City	−2	24	1.00	−0.13	South Pass City	2.56	Deaver	0.02
Alaska [September]	49.5	+4.2	Kodiak	80	12	2 stations	22	[2]20	3.32	−0.93	Mile Seven (Cordova).	19.64	McKinley Park	0.00
Hawaii	75.1	+1.4	Kaanapali	95	20	do	52	[2]5	4.38	−1.78	Hilos-Manawaiopuna Divide.	17.00	2 stations	0.00
Porto Rico	78.9	+0.7	San German	100	18	Cayey	58	22	6.09	−2.12	Maricao	29.30	Ponce	1.74

[1] For description of tables and charts see REVIEW, January, 1929, p. 36.

[2] Other dates also.

TABLE 1.—*Climatological data for weather bureau stations, October, 1929*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	°*F.*		°*F.*	°*F.*		°*F.*	° *F.*	° *F.*	° *F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
New England							**50.0**	**−1.1**										**72**	**2.59**	**−0.7**										**5.5**		
Eastport	76	67	85	29.89	29.97	−0.03	46.3	−1.2	61	3	52	27	30	40	21	43	40	79	1.67	−1.9	13	6,492	w.	30	e.	2	6	4	21	7.5	0.3	0.0
Greenville, Me	1,070	6	----	28.80	29.98	------	43.1	------	68	20	52	20	30	34	35	----	----	----	3.12	------	15	5,695	nw.	39	------	27	7	8	16	----	4.5	----
Portland, Me	103	82	117	29.90	30.02	−.02	48.8	−1.1	69	13	56	29	9	41	32	43	38	73	3.00	−0.1	8	5,820	w.	31	se.	23	12	7	12	5.6	T.	0.0
Concord	289	70	79	29.69	30.01	−.04	48.1	−1.6	76	20	59	23	10	38	40	----	----	----	2.06	−0.8	7	4,119	nw.	27	sw.	27	11	8	12	5.5	0.0	0.0
Burlington	403	11	48	29.56	30.00	−.04	46.9	−2.3	73	21	55	26	11	39	31	----	----	----	2.87	−0.1	17	7,353	nw.	40	se.	22	6	9	16	6.6	T.	0.0
Northfield	876	12	60	------	30.03	−.01	44.0	−1.5	75	20	55	19	11	33	42	----	----	81	1.83	−1.0	14	4,302	s.	26	s.	23	3	12	16	6.8	T.	0.0
Boston	125	106	165	29.88	30.02	−.03	53.2	−0.4	78	20	62	34	29	44	30	46	40	67	2.38	−0.8	5	5,832	nw.	30	nw.	7	10	10	11	5.6	0.0	0.0
Nantucket	12	14	90	30.01	30.02	−.03	53.6	−0.6	70	21	59	37	30	48	18	49	45	75	2.22	−1.2	8	11,766	sw.	42	ne.	2	14	8	9	5.1	T.	0.0
Block Island	26	11	46	29.99	30.02	−.03	53.6	−1.3	70	2	59	36	29	48	21	49	44	72	1.96	−1.6	8	13,144	sw.	42	w.	17	14	10	7	4.3	0.0	0.0
Providence	160	215	251	29.85	30.03	−.02	51.9	−0.3	74	7	61	30	30	43	29	45	39	66	2.70	−0.4	7	7,963	nw.	39	se.	23	17	4	10	4.1	0.0	0.0
Hartford	159	122	----	29.87	30.04	−.02	51.6	+0.4	74	21	61	30	11	42	34	----	----	----	4.02	+0.5	8	------	nw.	----	----	----	13	8	10	4.9	0.0	0.0
New Haven	106	74	153	29.93	30.05	−.01	51.8	−2.0	75	7	60	32	18	43	28	45	39	65	3.75	+0.1	9	6,562	n.	34	se.	22	14	10	7	4.3	T.	0.0
Middle Atlantic States							**54.4**	**−2.0**										**71**	**5.16**	**+2.1**										**5.1**		
Albany	97	107	115	29.93	30.03	−.03	50.3	−1.8	75	20	59	29	11	42	30	44	40	72	2.32	−0.4	8	4,660	sw.	25	se.	22	11	9	11	5.2	T.	0.0
Binghamton	871	10	84	29.10	30.04	−.02	48.6	−1.4	77	20	57	24	11	40	39	----	----	----	4.58	+1.6	10	4,066	nw.	23	sw.	27	4	9	18	7.2	T.	0.0
New York	314	414	454	29.71	30.05	−.01	54.0	−2.3	73	7	62	34	18	46	25	47	41	67	5.16	+1.6	7	11,968	nw.	60	nw.	17	9	12	10	6.0	T.	0.0
Bellefonte	1,050	5	36	28.94	30.06	------	48.0	------	79	20	59	26	10	37	47	42	37	70	7.44	------	10	------	sw.	----	----	----	6	10	15	6.5	T.	0.0
Harrisburg	374	94	104	29.67	30.08	.00	52.4	−2.4	73	27	61	34	11	44	29	46	40	67	7.10	+4.2	9	4,844	w.	29	se.	22	10	9	12	5.5	0.0	0.0
Philadelphia	114	123	367	29.94	30.07	.00	55.8	−2.0	77	7	64	37	18	48	27	49	43	69	3.50	+0.8	8	9,815	sw.	46	s.	2	9	12	10	5.1	0.0	0.0
Reading	325	81	98	29.71	30.06	------	53.3	------	76	20	62	34	11	44	35	46	41	68	5.45	+2.3	8	4,430	nw.	31	se.	22	11	11	9	5.4	0.0	0.0
Scranton	805	111	119	29.19	30.06	−.01	50.2	−1.7	77	20	59	28	11	41	37	44	38	69	4.20	+1.2	8	4,877	sw.	27	nw.	17	5	13	13	6.5	T.	0.0
Atlantic City	52	37	172	30.00	30.06	−.01	55.7	−1.2	78	7	62	35	18	49	22	50	45	70	4.30	+1.1	9	12,347	w.	60	e.	2	14	10	7	4.3	0.0	0.0
Cape May	17	13	49	------	------	------	56.0	−3.6	77	7	64	37	11	48	25	51	47	74	2.62	------	7	------	nw.	----	----	----	13	13	5	----	0.0	0.0
Sandy Hook	22	10	55	30.02	30.04	------	54.2	------	72	7	60	37	11	48	22	48	43	72	4.72	+0.9	7	11,391	sw.	48	ne.	2	11	10	10	5.2	0.0	0.0
Trenton	190	159	183	29.84	30.05	------	53.2	------	75	20	62	34	18	44	30	47	42	72	3.51	+0.7	9	7,514	sw.	35	nw.	17	9	12	10	5.2	0.0	0.0
Baltimore	123	100	215	29.93	30.06	−.02	56.2	−2.0	79	7	65	38	18	47	30	49	44	69	6.77	+3.9	9	7,391	sw.	48	se.	2	13	9	9	4.8	T.	0.0
Washington	112	62	85	29.94	30.06	−.02	55.6	−1.8	78	7	66	36	11	46	35	48	44	73	4.82	+2.0	8	4,397	nw.	28	nw.	17	12	10	9	4.9	0.0	0.0
Cape Henry	18	8	54	30.04	30.06	------	61.2	------	80	13	68	41	26	54	29	54	50	71	5.24	+2.2	8	9,278	sw.	46	ne.	1	18	6	7	3.9	0.0	0.0
Lynchburg	681	153	188	29.34	30.08	−.01	55.8	−2.7	77	20	66	36	11	45	37	48	43	71	5.21	+2.1	9	4,923	w.	27	n.	3	16	7	8	4.2	0.0	0.0
Norfolk	91	170	205	29.98	30.08	+.01	61.1	−1.4	79	7	69	41	26	53	27	53	48	69	5.66	+2.6	8	8,992	ne.	44	s.	2	20	4	7	3.7	0.0	0.0
Richmond	144	11	52	29.92	30.08	.00	58.0	−1.6	80	7	68	39	18	48	34	50	46	74	6.99	+4.1	7	5,552	ne.	32	sw.	22	15	9	7	4.0	0.0	0.0
Wytheville	2,304	49	55	27.70	30.09	.00	51.2	−2.4	74	20	61	33	9	42	39	46	43	80	8.06	+5.2	7	4,549	w.	26	nw.	2	13	7	11	5.0	0.0	0.0
South Atlantic States							**62.9**	**−1.4**										**76**	**5.31**	**+2.1**										**4.0**		
Asheville	2,253	70	84	27.74	30.10	+.01	53.2	−2.1	72	19	63	34	26	44	35	47	44	78	4.75	+2.0	10	5,323	nw.	25	n.	25	15	7	9	4.7	0.0	0.0
Charlotte	779	55	62	29.24	30.08	.00	59.0	−2.7	78	7	69	39	25	49	34	51	46	70	6.47	+3.5	8	3,274	ne.	21	n.	1	16	7	8	3.9	0.0	0.0
Greensboro	886	5	56	29.13	30.10	------	55.3	------	78	16	67	32	26	43	44	49	47	85	6.60	------	8	5,436	ne.	31	ne.	2	17	8	6	3.6	0.0	0.0
Hatteras	11	5	50	30.04	30.05	−.01	65.2	−0.7	80	2	71	48	19	60	20	60	57	76	4.09	−0.9	6	9,518	ne.	48	se.	22	17	8	6	3.9	0.0	0.0
Raleigh	376	103	110	29.67	30.07	.00	59.7	−2.3	79	13	69	42	26	50	30	52	48	73	9.59	+6.7	7	4,646	ne.	28	s.	2	20	4	7	3.7	0.0	0.0
Wilmington	78	81	91	29.99	30.07	+.01	64.1	−1.2	84	1	74	45	25	55	29	57	54	78	5.81	+2.5	6	4,648	ne.	30	sw.	2	18	9	4	3.2	0.0	0.0
Charleston	48	11	92	30.00	30.05	−.01	67.0	−0.8	83	1	74	47	25	60	24	60	57	77	1.71	−1.6	4	7,729	ne.	36	s.	1	16	10	5	4.0	0.0	0.0
Columbia, S. C	351	41	57	29.69	30.07	.00	62.2	−2.1	82	7	72	41	26	52	33	54	50	74	5.62	+3.1	5	4,731	ne.	26	ne.	1	17	6	8	3.9	0.0	0.0
Due West	711	10	55	29.32	30.10	------	59.2	------	82	17	69	35	25	49	32	----	----	----	8.78	------	5	6,410	ne.	39	ne.	1	16	7	8	4.1	0.0	0.0
Greenville, S. C	1,039	139	146	28.97	30.07	------	59.4	−0.8	80	17	68	41	23	51	29	52	47	71	7.58	+4.5	9	6,152	ne.	36	ne.	1	15	8	8	4.1	0.0	0.0
Augusta	182	62	77	29.85	30.04	−.03	64.2	−1.1	84	17	74	39	26	54	35	56	52	75	11.06	+8.6	4	3,710	ne.	28	n.	1	16	8	7	4.0	0.0	0.0
Savannah	65	150	194	29.97	30.04	−.01	67.5	−0.4	84	17	76	46	25	59	28	60	57	76	0.95	−2.0	4	8,044	ne.	40	se.	1	13	8	10	4.7	0.0	0.0
Jacksonville	43	209	245	29.97	30.02	.00	70.4	−0.7	82	17	78	50	25	63	24	63	59	75	0.83	−3.6	8	8,343	e.	61	sw.	1	18	8	5	3.8	0.0	0.0
Florida Peninsula							**74.8**	**−2.0**										**80**	**9.77**	**+3.9**										**5.0**		
Key West	22	10	64	29.92	29.94	.00	76.3	−2.8	86	1	80	64	27	72	16	72	70	84	8.43	+2.4	17	6,580	e.	26	nw.	22	13	3	15	5.9	0.0	0.0
Miami	25	141	168	29.94	29.97	−.01	75.2	−1.8	88	1	80	60	26	70	20	70	68	79	20.18	+11.7	17	6,773	e.	31	ne.	10	7	8	16	6.6	0.0	0.0
Tampa	35	79	87	29.95	29.99	+.01	73.0	−1.3	91	6	81	53	26	65	26	65	62	76	0.69	−2.4	6	4,678	ne.	23	sw.	1	13	12	6	4.5	0.0	0.0
Titusville	44	5	----	29.94	29.98	------	72.4	------	89	1	82	49	23	63	31	----	----	----	5.10	------	6	------	nw.	----	----	----	17	9	5	2.9	0.0	0.0
East Gulf States							**65.1**	**−1.4**										**73**	**3.62**	**+0.7**										**3.9**		
Atlanta	1,173	190	216	28.83	30.07	.00	59.6	−3.4	78	7	67	38	25	52	25	52	47	69	3.04	+0.4	9	8,207	e.	29	nw.	2	15	7	9	4.6	0.0	0.0
Macon	370	78	87	29.66	30.06	.00	63.1	−1.4	83	17	73	40	26	53	36	57	54	80	7.49	+5.2	7	4,465	ne.	35	ne.	1	18	5	8	3.8	0.0	0.0
Thomasville	273	49	58	29.73	30.02	−.02	67.4	−0.8	86	8	78	44	25	57	30	59	56	75	2.39	−0.6	4	3,239	ne.	21	nw.	1	15	8	8	4.0	0.0	0.0
Apalachicola	36	42	49	29.98	30.02	------	69.1	------	83	18	76	52	25	62	19	63	59	76	1.50	−1.7	4	6,166	ne.	38	se.	29	19	7	5	3.4	0.0	0.0
Pensacola	56	149	185	29.97	30.03	.00	68.6	−1.3	84	8	75	48	25	62	22	62	58	74	2.93	−1.3	5	9,280	n.	38	se.	29	19	5	7	3.8	0.0	0.0
Anniston	741	9	57	29.29	30.09	+.02	59.7	−2.7	82	17	70	34	24	49	38	----	----	----	3.02	+0.4	9	3,812	se.	18	nw.	2	19	4	8	3.6	0.0	0.0
Birmingham	700	11	48	29.30	30.07	.00	62.4	−2.4	84	17	72	38	25	52	34	54	50	75	4.74	+2.3	8	4,449	e.	27	se.	28	19	2	10	4.1	0.0	0.0
Mobile	57	125	161	29.97	30.03	−.01	68.4	−0.9	86	18	77	45	25	60	24	60	56	73	4.49	+0.9	6	6,758	n.	33	n.	28	16	8	7	3.9	0.0	0.0
Montgomery	223	100	112	29.80	30.06	.00	64.9	−1.7	84	7	74	42	26	56	29	57	52	69	3.21	+0.8	7	4,469	e.	23	se.	28	19	4	8	3.8	0.0	0.0
Corinth	469	6	----	------	------	------	61.9	------	85	19	74	35	26	50	40	----	----	----	4.16	------	8	------	se.	----	----	----	10	15	6	----	0.0	0.0
Meridian	375	87	95	29.65	30.05	−.01	64.0	−0.3	83	17	74	37	25	53	36	56	52	75	1.82	−0.6	9	3,612	ne.	28	se.	28	17	6	8	3.7	0.0	0.0
Vicksburg	247	65	73	29.78	30.06	.00	66.4	−0.3	85	30	76	42	25	57	24	58	53	70	2.55	−0.2	7	4,500	se.	22	se.	30	18	6	7	4.0	0.0	0.0
New Orleans	53	76	84	29.97	30.02	−.01	71.2	+0.2	84	8	78	53	24	64	20	63	59	72	6.26	+3.0	5	4,313	ne.	16	e.	10	17	6	8	3.9	0.0	0.0
West Gulf States							**69.1**	**+1.2**										**71**	**2.62**	**−0.5**										**4.1**		
Shreveport	249	77	93	29.76	30.03	−.02	67.5	+0.9	86	18	77	40	24	58	27	58	53	68	1.30	−1.4	7	3,550	se.	24	s.	30	17	9	5	4.0	0.0	0.0
Bentonville	1,303	11	44	28.65	30.02	−.03	58.4	+0.4	81	17	69	31	25	48	33	----	----	----	5.92	------	11	3,031	se.	28	n.	20	16	9	6	----	0.0	0.0
Fort Smith	457	79	94	29.55	30.03	−.02	62.8	0.0	83	17	72	34	24	54	36	56	51	74	4.09	+1.1	11	4,581	e.	24	nw.	20	12	9	10	5.0	0.0	0.0
Little Rock	357	136	153	29.67	30.04	−.02	64.1	+0.5	85	17	73	38	24	55	29	55	50	67	4.76	+2.0	8	5,076	e.	26	nw.	23	13	7	11	4.8	0.0	0.0
Austin	605	136	148	29.37	30.00	------	71.5	+3.2	98	4	83	48	22	60	32	61	55	66	1.90	−1.3	6	4,136	se.	31	nw.	19	14	10	7	4.0	0.0	0.0
Brownsville	57	83	100	29.91	29.97	------	75.0	+0.1	92	5	83	50	26	67	26	67	64	80	1.23	−2.1	5	5,463	se.	27	ne.	20	14	11	6	3.9	0.0	0.0
Corpus Christi	20	11	78	29.98	29.99	−.01	74.4	+1.2	91	4	81	50	25	68	22	67	65	77	1.69	−0.8	10	6,628	e.	25	n.	22	13	7	11	4.6	0.0	0.0
Dallas	512	220	227	29.48	30.02	------	67.6	------	88	4	77	37	24	58	29	----	----	----	1.63	−1.1	8	7,331	se.	28	w.	23	15	12	4	3.6	0.0	0.0
Fort Worth	670	106	114	29.29	30.00	−.03	68.6	+1.9	90	4	79	39	25	58	33	59	54	66	2.12	−0.7	7	4,976	se.	23	s.	3	12	10	9	4.8	0.0	0.0
Galveston	54	106	114	29.97	30.03	.00	73.3	+0.6	86	5	78	58	24	69	17	66	62	74	4.02	−0.3	4	6,651	se.	23	s.	4	16	8	7	4.0	0.0	0.0
Groesbeck	461	11	56	29.54	30.02	------	68.8	------	89	4	80	36	25	57	36	----	----	----	2.36	−1.8	5	5,548	se.	25	sw.	4	15	12	4	3.9	0.0	0.0
Houston	138	292	314	29.88	30.02	------	72.2	+1.9	90	4	81	52	25	63	25	----	----	----	2.97	−0.8	6	7,865	e.	35	nw.	20	16	7	8	4.1	0.0	0.0
Palestine	510	64	72	29.50	30.03	.00	68.4	+1.2	88	11	78	39	24	58	29	60	55	70	3.38	+0.1	6	4,100	s.	20	nw.	21	16	8	7	3.9	0.0	0.0
Port Arthur	34	58	66	29.98	30.02	------	71.8	------	87	5	80	47	22	64	27	64	60	76	2.85	------	5	4,650	e.	22	n.	21	20	6	5	3.5	0.0	0.0
San Antonio	693	119	132	29.28	30.00	−.01	72.0	+1.5	97	4	82	47	25	62	31	62	57	67	1.60	−0.6	7	3,892	ne.	24	nw.	19	14	9	8	4.5	0.0	0.0
Taylor	583	55	63	29.44	30.05	+.03	70.2	+1.9	97	4	82	46	25	59	31	----	----	----	3.64	+0.6	6	4,242	nw.	30	nw.	30	17	9	5	3.5	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, October, 1929*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	°*F.*		°*F.*	°*F.*		°*F.*	° *F.*	° *F.*	° *F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
							55.7	**−2.0**										**74**	**3.94**	**+1.3**										**5.5**		
Chattanooga	762	190	215	29.26	30.07	−.02	59.3	−2.6	79	18	68	39	25	51	32	52	47	69	3.12	+0.1	9	5,130	sw.	25	nw.	2	14	6	11	4.8	0.0	0.0
Knoxville	995	102	111	29.02	30.08	−.01	57.4	−2.5	77	7	67	35	26	48	32	51	47	74	1.33	−1.3	6	3,949	ne.	25	sw.	23	12	9	10	4.8	0.0	0.0
Memphis	399	76	97	29.62	30.05	−.02	63.0	−0.3	81	16	71	39	24	55	24	56	52	75	6.88	+4.2	7	4,284	e.	25	n.	20	16	7	8	4.1	0.0	0.0
Nashville	546	168	191	29.51	30.10	+.02	59.4	−1.6	80	16	68	39	24	50	35	51	45	67	4.05	+1.6	10	5,933	w.	29	s.	31	13	6	12	4.9	0.0	0.0
Lexington	989	193	230	29.01	30.09	+.01	55.1	−2.3	75	16	63	32	24	47	27				2.99	+0.4	10	8,791	sw.	33	sw.	22	9	5	17	6.1	T.	0.0
Louisville	525	188	234	29.50	30.08	.00	57.0	−2.3	79	16	65	34	24	49	33	50	45	73	4.40	+1.8	10	7,296	sw.	31	nw.	21	10	9	12	5.4	T.	0.0
Evansville	431	76	116	29.62	30.09	+.01	58.4	−1.0	82	16	66	34	24	50	29	51	46	73	1.68	−1.1	14	5,772	e.	25	nw.	22	13	5	13	5.1	T.	0.0
Indianapolis	822	194	230	29.17	30.06	−.01	53.4	−2.3	77	19	62	32	23	45	29	46	41	70	3.66	+0.9	11	7,863	sw.	33	w.	22	14	5	12	5.3	0.4	0.0
Royal Center	736	11	55	29.25	30.06	------	49.7	------	75	19	59	30	25	40	33	----	----	----	3.71	+0.7	13	7,132	sw.	31	e.	29	13	5	13	5.5	4.0	0.0
Terre Haute	575	96	129	29.44	30.66	------	55.0	------	80	16	64	33	23	46	31	48	44	74	3.54	+0.8	11	6,207	sw.	28	nw.	22	14	4	13	5.3	0.6	0.0
Cincinnati	627	11	51	29.39	30.08	.00	54.1	−1.6	78	16	64	32	23	45	39	47	43	75	3.24	+0.7	12	4,969	sw.	26	sw.	22	10	9	12	5.8	T.	0.0
Columbus	822	179	222	29.19	30.07	−.01	53.1	−2.1	76	19	61	35	24	45	32	47	44	77	4.09	+1.6	13	6,914	nw.	34	w.	16	9	9	13	5.8	T.	0.0
Dayton	899	137	173	29.10	30.06	------	53.2	−1.8	74	16	62	33	23	45	32	47	44	77	3.64	+1.1	10	6,161	sw.	33	w.	22	10	5	16	6.0	T.	0.0
Elkins	1,947	59	67	28.02	30.11	+.01	49.4	−2.9	76	19	61	28	18	38	47	44	40	80	7.28	+4.4	12	3,894	w.	26	w.	16	5	9	17	6.9	T.	0.0
Parkersburg	637	77	82	29.43	30.09	+.01	54.6	−1.5	77	20	64	33	18	45	38	47	43	74	4.34	+1.9	13	3,810	se.	18	sw.	22	7	8	16	6.5	T.	0.0
Pittsburgh	842	353	410	29.15	30.07	−.01	52.2	−3.5	74	20	60	34	24	44	32	46	42	73	5.07	+2.6	14	7,127	sw.	41	s.	22	7	12	12	6.1	T.	0.0
Lower Lake Region							**50.2**	**−1.9**										**73**	**3.55**	**+0.7**										**6.5**		
Buffalo	767	247	280	29.19	30.03	−.02	49.5	−2.4	72	20	56	30	10	43	22	47	44	84	2.25	−1.0	11	12,282	sw.	54	w.	25	6	11	14	6.8	T.	0.0
Canton	448	10	61	29.53	30.01	------	45.3	−1.9	75	20	54	23	10	36	37	----	----	----	3.23	+0.2	14	6,351	sw.	37	sw.	27	9	7	15	6.1	0.3	0.0
Ithaca	836	5	100	29.13	30.05	------	47.2	------	74	20	56	23	10	38	41	42	38	75	4.20	+1.2	11	7,182	nw.	40	sw.	22	1	8	22	8.1	0.1	0.0
Oswego	335	76	91	29.66	30.03	−.02	48.8	−2.4	76	20	56	28	11	42	31	43	37	67	2.66	−0.6	12	7,233	s.	31	se.	22	4	8	19	7.5	T.	0.0
Rochester	523	86	102	29.47	30.05	.00	49.8	−1.7	77	20	57	31	18	42	28	43	37	66	3.87	+1.2	8	5,966	sw.	30	w.	27	5	8	18	7.0	T.	0.0
Syracuse	596	65	79	29.40	30.05	−.01	49.8	−1.2	77	20	57	28	10	42	29	----	----	----	3.45	+0.6	14	4,977	s.	26	nw.	17	4	12	15	7.1	T.	0.0
Erie	714	130	166	29.26	30.04	−.01	51.2	−2.2	76	20	58	33	28	44	23	46	41	72	1.65	−2.0	10	10,908	nw.	55	e.	22	5	10	16	6.6	T.	0.0
Cleveland	762	267	337	29.21	30.04	−.02	52.2	−1.4	73	20	58	34	24	46	24	46	40	66	2.68	−0.1	11	11,186	sw.	46	nw.	7	6	10	15	6.6	T.	0.0
Sandusky	629	5	67	29.36	30.04	−.02	52.8	−1.5	75	20	60	34	24	45	32	----	----	----	5.00	+2.6	12	6,625	sw.	30	sw.	23	9	6	16	6.1	T.	0.0
Toledo	628	208	243	29.36	30.05	.00	51.2	−2.2	72	19	59	34	24	44	26	46	41	74	5.70	+3.3	11	10,017	sw.	43	sw.	23	15	2	14	5.1	T.	0.0
Fort Wayne	856	113	124	29.12	30.05	------	50.4	−3.3	75	19	59	32	23	42	29	45	41	77	3.91	+1.3	12	6,521	sw.	29	sw.	23	11	6	14	5.8	1.4	0.0
Detroit	730	218	258	29.24	30.04	−.01	51.4	−1.1	71	19	59	32	24	44	23	47	43	78	3.99	+1.6	13	7,665	sw.	30	sw.	23	13	5	13	5.6	T.	0.0
Upper Lake Region							**47.8**	**−0.8**										**76**	**3.11**	**+0.4**										**6.1**		
Alpena	609	13	92	29.35	30.02	−.01	46.2	−0.9	69	19	54	27	10	38	32	42	39	79	4.08	+1.4	11	8,473	nw.	36	se.	23	6	7	18	6.7	T.	0.0
Escanaba	612	54	60	29.36	30.04	+.03	46.0	0.0	68	25	53	25	9	39	35	42	38	77	2.16	−0.5	8	8,483	n.	48	n.	23	10	9	12	5.5	T.	0.0
Grand Haven	632	54	89	29.33	30.02	−.01	48.1	−2.6	65	19	55	27	28	41	26	45	42	80	3.04	0.0	11	8,148	nw.	29	w.	12	10	6	15	5.9	0.0	0.0
Grand Rapids	707	70	87	29.26	30.04	.00	49.4	−1.8	72	19	58	29	28	41	31	44	40	74	3.40	+0.6	7	3,962	w.	20	nw.	7	9	4	18	6.6	0.0	0.0
Houghton	668	64	99	29.31	30.04	+.04	45.8	+0.1	80	15	53	30	9	39	33	----	----	----	3.35	+0.4	14	7,254	e.	34	n.	23	8	7	16	6.8	2.5	0.0
Lansing	878	6	49	29.08	30.04	------	47.6	−2.7	74	19	57	27	9	38	33	44	41	87	4.09	+1.6	13	4,149	sw.	19	n.	22	11	6	14	5.8	0.1	0.0
Ludington	637	60	66	29.32	30.02	------	48.0	−1.7	64	15	54	28	9	42	24	45	41	80	3.06	+0.1	10	7,278	n.	30	n.	23	13	3	15	5.4	0.0	0.0
Marquette	734	77	111	29.23	30.04	+.03	46.6	−0.1	75	15	54	30	28	40	26	42	37	74	4.53	+1.8	11	7,629	nw.	35	sw.	5	7	6	18	7.0	1.2	0.0
Port Huron	638	70	120	29.32	30.02	−.02	49.3	−1.2	70	6	57	32	5	42	28	44	40	73	3.50	+1.0	11	8,833	nw.	35	s.	22	9	9	13	5.7	T.	0.0
Sault Sainte Marie	614	11	52	29.33	30.04	+.03	43.8	−0.8	68	15	51	24	28	36	30	40	37	80	2.52	−1.2	15	6,426	nw.	42	ne.	22	8	8	15	6.5	2.3	0.0
Chicago	673	7	131	29.32	30.04	.00	53.1	−0.9	77	15	59	34	23	47	29	47	42	71	3.06	+0.5	12	8,143	sw.	34	nw.	22	12	5	14	5.6	0.7	0.0
Green Bay	617	109	141	29.36	30.02	.00	48.4	−0.1	80	15	57	31	4	40	34	43	38	73	1.86	−0.7	8	8,052	sw.	37	n.	22	6	9	16	6.9	T.	0.0
Milwaukee	681	125	221	29.30	30.03	.00	51.3	+0.2	79	15	58	32	23	44	30	45	40	71	2.46	+0.1	12	10,806	w.	44	n.	22	11	6	14	6.0	1.2	0.0
Duluth	1,133	5	47	28.82	30.05	+.05	46.1	+2.0	82	15	55	28	8	37	34	40	35	73	2.47	+0.2	8	9,203	nw.	36	n.	23	10	8	13	5.5	0.3	0.0
North Dakota							**47.0**	**+3.2**										**74**	**2.16**	**+1.0**										**4.6**		
Moorhead	940	50	58	29.02	30.06	+.06	47.6	+3.1	80	15	58	23	23	37	35	41	37	76	3.13	+1.4	9	5,585	s.	24	nw.	6	14	9	8	4.6	4.8	T.
Bismarck	1,674	8	57	28.26	30.06	+.07	48.6	+3.7	83	5	60	26	24	37	40	41	37	74	1.82	+0.9	7	5,143	nw.	26	se.	28	16	5	10	4.5	4.8	3.5
Devils Lake	1,478	11	44	28.47	30.06	+.07	44.5	+2.1	79	17	55	19	23	34	39	38	34	77	2.12	+0.9	6	5,877	se.	31	nw.	31	14	5	12	4.9	9.7	7.0
Ellendale	1,457	10	56	28.48	30.07	------	47.2	------	84	5	59	23	23	36	43	----	----	----	3.30	+2.1	9	8,888	nw.	35	nw.	26	13	9	9	4.9	7.3	5.3
Grand Forks	833	12	67	----	----	----	46.1	------	76	14	57	23	23	35	37	39	----	----	2.34	------	8	------	nw.	----	s.	17	18	5	8	----	5.2	0.7
Williston	1,878	41	48	28.06	30.06	+.08	47.2	+3.8	82	16	60	23	12	34	45	40	33	67	0.45	−0.4	6	4,266	e.	29	e.	28	17	6	8	4.2	1.8	T.
Upper Mississippi Valley							**52.9**	**−0.2**										**74**	**2.84**	**+0.4**										**5.1**		
Minneapolis	918	102	208	29.03	30.02	------	49.8	+0.9	79	15	58	29	23	41	32	----	----	----	2.17	+0.1	9	7,884	s.	39	n.	23	12	7	12	5.5	1.9	0.0
St. Paul	837	236	261	29.13	30.05	+.04	49.0	+0.4	78	15	58	29	23	40	33	----	----	----	2.45	+0.2	8	8,261	se.	42	n.	23	12	5	14	5.6	2.0	0.0
La Crosse	714	11	48	29.28	30.05	+.03	49.8	−0.5	84	15	60	30	23	40	38	43	40	78	1.73	−0.6	10	2,848	s.	18	n.	22	11	8	12	5.4	3.1	0.0
Madison	974	70	78	29.00	30.06	+.03	49.7	−0.6	79	15	57	32	23	42	29	44	40	75	1.82	−0.6	11	6,189	nw.	27	ne.	21	13	5	13	5.4	2.5	0.0
Wausau	1,247	4	64	----	----	----	47.0	------	76	15	56	27	28	38	30	----	----	----	2.04	−0.7	10	------	w.	----	----	----	9	4	18	----	1.1	----
Charles City	1,015	10	51	28.98	30.07	+.05	48.9	+0.3	80	15	59	28	23	38	39	43	39	77	1.49	−0.8	9	4,330	se.	23	nw.	22	13	4	14	5.1	1.2	0.0
Davenport	606	71	79	29.38	30.04	.00	53.2	−0.5	80	15	62	30	23	44	30	46	41	73	3.77	+1.4	12	6,313	e.	33	ne.	28	13	6	12	5.1	1.1	0.0
Des Moines	861	84	97	29.13	30.04	+.01	53.6	+0.2	80	14	64	32	23	43	38	47	42	73	2.74	+0.2	9	6,394	e.	30	e.	28	14	4	13	5.0	T.	0.0
Dubuque	700	81	96	29.30	30.05	+.01	50.7	−1.2	80	15	60	30	23	42	32	45	40	72	2.10	−0.4	11	4,121	nw.	24	n.	22	11	5	15	5.7	3.0	0.0
Keokuk	614	64	78	29.38	30.06	+.01	54.8	−0.6	78	19	64	31	23	46	30	48	44	73	4.27	+2.0	11	4,666	e.	22	ne.	28	16	3	12	4.4	0.4	0.0
Cairo	358	87	93	29.68	30.06	−.01	59.5	−0.9	81	16	68	34	25	51	29	52	48	73	1.08	−1.7	6	5,171	n.	27	se.	31	12	5	14	5.4	0.0	0.0
Peoria	609	11	45	29.40	30.07	+.02	53.0	+1.0	80	15	63	30	25	43	36	46	43	78	3.89	+1.6	12	4,185	e.	20	w.	12	15	4	12	4.6	3.3	0.0
Springfield, Ill.	636	154	191	29.37	30.05	.00	54.6	−1.2	79	19	63	31	23	46	30	49	45	77	3.33	+0.8	12	8,491	sw.	35	se.	31	14	4	13	4.7	2.4	0.0
Hannibal	534	74	109	29.48	30.05	.00	56.1	+0.1	80	16	66	32	23	47	32	----	----	----	4.67	+2.3	10	5,539	sw.	42	s.	31	18	1	12	4.2	0.3	0.0
St. Louis	568	265	303	29.44	30.05	−.01	58.4	+0.1	81	16	66	35	23	51	26	51	45	68	4.99	+2.3	11	7,669	e.	26	n.	22	14	4	13	4.9	T.	0.0
Missouri Valley							**54.9**	**+1.2**										**71**	**4.25**	**+2.2**										**4.9**		
Columbia, Mo.	784	6	84	29.21	30.05	.00	57.4	+0.8	82	16	67	32	25	48	33	----	----	----	6.96	+4.4	11	4,846	sw.	20	nw.	23	14	8	9	4.6	T.	0.0
Kansas City	963	161	181	29.00	30.04	.00	58.8	+1.1	83	16	68	34	23	50	26	51	46	70	6.72	+3.8	12	6,322	e.	32	nw.	20	15	5	11	4.8	0.0	0.0
St. Joseph	967	11	49	29.00	30.04	------	56.8	------	82	16	67	34	23	47	33	49	44	74	6.05	+3.4	11	5,088	se.	25	nw.	22	15	6	10	4.8	0.0	0.0
Springfield, Mo.	1,324	98	104	28.66	30.06	+.01	58.6	+0.4	82	17	67	35	25	50	27	51	46	71	5.55	+2.5	10	6,288	se.	29	nw.	20	13	10	8	4.5	0.0	0.0
Iola	984	11	50	28.99	30.04	.00	59.4	+1.6	86	17	71	28	25	48	41	----	----	----	4.32	+1.3	12	3,138	s.	22	n.	20	9	13	9	5.2	0.0	0.0
Topeka	987	92	107	----	----	----	58.6	+1.6	84	16	69	33	23	48	35	----	----	----	5.96	+3.5	12	5,437	sw.	26	e.	28	12	8	11	4.9	0.0	0.0
Lincoln	1,189	11	81	28.77	30.04	+.01	54.6	+0.4	80	17	64	30	23	45	35	48	44	75	4.57	+2.7	11	5,846	s.	29	nw.	23	12	6	13	5.2	0.0	0.0
Omaha	1,105	115	122	28.86	30.05	+.02	55.0	+0.7	80	14	64	30	23	46	32	48	42	68	2.69	+0.5	11	4,901	n.	30	nw.	23	14	7	10	4.7	0.0	0.0
Valentine	2,598	47	54	27.34	30.08	+.07	50.3	+1.0	86	5	64	26	24	37	47	42	36	68	3.01	+1.9	11	5,094	w.	28	sw.	8	14	7	10	4.6	13.9	7.0
Sioux City	1,135	94	164	28.83	30.06	+.04	52.4	+1.5	81	15	62	26	23	43	37	46	41	70	2.23	+0.5	7	7,228	nw.	39	e.	28	12	7	12	5.4	T.	0.0
Huron	1,306	59	74	28.66	30.08	+.07	50.2	+2.5	84	15	61	25	23	39	41	42	37	71	1.62	+0.3	8	6,092	w.	31	w.	11	15	5	11	4.7	4.7	3.0
Pierre	1,572	70	75	28.39	30.06	+.05	51.7	+1.9	86	5	63	28	24	40	41	44	38	70	2.92	+2.1	9	4,856	nw.	25	e.	28	17	2	12	4.5	9.9	4.7
Yankton	1,233	49	57	28.72	30.04	+.03	52.0	+0.9	85	15	62	28	23	42	39	----	----	----	2.70	+1.3	9	4,606	w.	25	nw.	23	9	9	13	5.9	T.	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, October, 1929*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	°*F.*		*F.*	°*F.*		°*F.*	° *F.*	° *F.*	° *F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Northern slope							**47.7**	**+2.5**										**62**	**1.06**	**0.0**										**4.3**		
Billings	3,140	5	----	----	----	----	49.2	----	82	17	66	16	23	32	50	----	----	----	1.14	----	6	----	nw.	----	----	----	16	9	6	----	T.	----
Havre	2,505	11	44	27.43	30.08	+0.10	48.6	+4.1	82	16	62	19	23	35	51	39	31	61	0.67	0.0	5	4,584	sw.	28	w.	4	14	11	6	4.2	T.	T.
Helena	4,110	87	112	25.90	30.13	+.10	47.7	+2.8	75	4	59	23	30	36	36	38	30	56	0.25	−0.6	5	5,351	sw.	30	sw.	30	9	12	10	5.6	0.3	0.0
Kalispell	2,973	48	56	27.04	30.12	+.11	45.4	+1.9	73	14	58	22	31	33	40	38	32	64	0.51	−0.6	4	3,380	nw.	18	w.	4	11	15	5	4.4	T.	0.0
Miles City	2,371	48	55	27.54	30.12	+.12	50.2	+3.7	81	16	63	26	24	38	43	41	34	63	1.05	+0.2	5	2,878	s.	28	n.	5	16	9	6	3.8	1.6	T.
Rapid City	3,259	50	58	26.68	30.12	+.11	50.5	+2.0	84	5	62	23	30	39	37	41	33	60	1.73	+0.8	9	4,982	w.	30	n.	21	17	6	8	4.1	8.8	4.6
Cheyenne	6,088	84	101	24.08	30.07	+.06	46.4	+1.6	78	5	58	12	31	35	37	37	28	56	1.47	+0.5	10	7,684	w.	28	se.	27	15	8	8	4.3	15.3	12.0
Lander	5,372	60	68	24.73	30.12	+.08	45.6	+2.1	78	5	61	15	30	31	42	37	30	63	1.36	0.0	7	2,577	sw.	21	nw.	17	18	9	4	3.4	10.9	7.8
Sheridan	3,790	10	47	26.18	30.12	----	46.6	----	80	16	63	13	24	30	58	37	30	65	0.71	−0.4	7	3,010	nw.	27	nw.	27	15	11	5	3.7	1.5	T.
Yellowstone Park	6,241	11	48	23.99	30.16	+.14	42.6	+1.1	67	16	56	17	23	30	41	33	25	57	1.27	−0.1	7	4,663	sw.	30	sw.	27	11	7	13	5.2	1.7	0.1
North Platte	2,821	11	51	27.12	30.06	+.04	52.6	+2.9	88	5	66	25	25	40	53	43	39	71	1.62	+0.6	10	4,286	n.	22	nw.	23	15	5	11	4.5	4.5	0.8
Middle Slope							**56.5**	**+0.6**										**66**	**2.71**	**+0.7**										**4.7**		
Denver	5,292	106	113	24.81	30.08	+.07	51.2	0.0	82	5	63	23	31	40	34	40	30	52	1.00	0.0	7	4,721	s.	28	nw.	3	17	6	8	3.9	16.2	4.0
Pueblo	4,685	80	86	25.32	30.01	+.02	52.8	+0.8	89	5	68	19	24	38	51	40	29	49	0.79	+0.1	3	3,618	nw.	25	nw.	8	19	8	4	3.4	7.0	2.9
Concordia	1,392	50	58	28.59	30.07	+.04	56.1	+0.2	83	16	66	32	23	47	34	49	46	77	3.82	+1.8	10	4,003	s.	25	n.	23	11	7	13	5.1	0.0	0.0
Dodge City	2,509	11	51	27.46	30.07	+.05	56.4	+0.3	84	16	68	27	31	45	43	48	44	73	0.85	−0.4	7	5,123	nw.	22	ne.	22	16	7	8	4.4	0.0	0.0
Wichita	1,358	139	158	28.59	30.02	−.01	59.6	+1.0	85	16	69	34	23	50	33	52	46	70	3.23	+0.6	9	6,734	s.	28	w.	29	9	13	9	5.6	0.0	0.0
Broken Arrow	765	11	56	29.21	30.04	----	61.8	----	83	16	71	35	24	52	31	----	----	----	4.82	+1.5	11	7,328	se.	36	s.	10	11	9	11	5.2	0.0	0.0
Oklahoma City	1,214	10	47	28.75	30.03	.00	62.8	+1.3	84	17	72	35	24	53	31	55	52	77	4.49	+1.6	10	5,120	s.	28	nw.	23	13	9	9	5.3	0.0	0.0
Southern Slope							**64.4**	**+1.3**										**65**	**2.08**	**+0.2**										**4.4**		
Abilene	1,738	10	52	28.22	30.02	+.01	66.5	+1.1	99	3	78	32	24	56	36	56	50	67	3.28	+0.8	8	4,814	s.	23	sw.	3	13	10	8	4.5	0.0	0.0
Amarillo	3,676	10	49	26.32	30.03	+.03	60.2	+2.5	91	3	72	27	24	49	34	50	44	68	3.28	+1.6	9	5,114	sw.	25	n.	22	13	10	8	4.3	1.5	0.0
Del Rio	944	64	71	29.00	29.98	.00	70.8	+0.8	97	4	80	48	28	61	32	60	54	63	1.19	−0.6	5	5,114	se.	27	nw.	30	17	7	7	3.8	0.0	0.0
Roswell	3,566	75	85	26.41	30.00	+.04	60.2	+0.7	93	3	72	26	24	48	39	50	42	61	0.58	−0.8	5	4,281	s.	34	s.	8	12	10	9	4.9	0.0	0.0
Southern Plateau							**62.5**	**+2.5**										**51**	**0.62**	**0.0**										**2.7**		
El Paso	3,778	152	175	26.21	29.96	+.04	63.8	+0.3	93	2	74	34	31	54	31	51	42	53	1.60	+0.8	8	6,189	e.	32	nw.	28	16	9	6	4.3	T.	0.0
Santa Fe	7,013	38	53	23.31	30.02	+.06	49.6	−0.8	77	1	61	21	30	38	33	40	33	63	1.43	+0.2	9	3,282	e.	17	e.	22	14	11	6	4.0	9.2	0.5
Flagstaff	6,907	10	59	23.44	29.97	+.05	47.6	+2.6	77	1	64	11	30	32	45	36	----	56	0.14	------	1	5,285	ne.	33	sw.	2	16	15	0	----	T.	0.0
Phoenix	1,108	10	107	28.72	29.85	−.03	74.7	+4.1	104	6	90	40	31	60	40	56	42	37	0.09	−0.4	1	2,973	e.	21	w.	28	24	6	1	1.5	0.0	0.0
Yuma	141	9	54	29.70	29.85	−.02	75.9	+2.6	105	6	91	41	31	60	40	59	48	44	T.	−0.3	0	2,121	sw.	17	w.	28	29	2	0	1.0	0.0	0.0
Independence	3,957	6	27	26.00	30.00	+.05	63.6	+6.1	90	5	79	32	30	48	42	44	----	----	0.00	−0.3	0	------	nw.	----	----	----	25	6	0	----	0.0	0.0
Middle Plateau							**52.8**	**+2.6**										**42**	**0.31**	**−0.5**										**2.4**		
Reno	4,532	74	81	25.54	30.04	+.05	54.0	+4.3	84	4	72	22	30	36	46	41	27	42	0.03	−0.3	1	3,335	w.	26	w.	6	24	7	0	1.5	0.0	0.0
Tonopah	6,090	12	20	----	----	----	55.6	----	77	5	65	22	29	46	28	41	23	30	T.	------	0	------	se.	----	----	----	----	----	----	----	----	----
Winnemucca	4,344	18	56	25.71	30.11	+.06	50.8	+2.5	84	5	71	12	30	30	56	37	22	38	0.01	−0.6	1	4,110	ne.	33	nw.	27	30	1	0	1.3	T.	0.0
Modena	5,473	10	43	24.67	30.00	+.04	50.4	+2.4	82	5	67	16	31	33	45	38	25	43	0.11	−0.6	2	5,473	w.	36	sw.	2	23	7	1	2.4	0.0	0.0
Salt Lake City	4,360	163	203	25.69	30.06	+.05	54.8	+2.3	81	5	65	32	28	44	36	45	37	53	0.98	−0.5	5	4,476	se.	39	nw.	27	16	11	4	3.6	3.0	0.0
Grand Junction	4,602	60	68	25.44	30.03	+.04	54.2	+1.4	83	2	66	29	24	42	35	42	31	49	0.41	−0.5	5	3,402	se.	25	sw.	28	20	4	7	3.3	1.0	0.0
Northern Plateau							**52.6**	**+2.7**										**50**	**0.53**	**−0.7**										**3.5**		
Baker	3,471	48	53	26.57	30.17	+.09	48.8	+2.2	78	15	65	19	30	33	42	39	28	48	0.16	−0.8	4	3,996	se.	15	nw.	28	16	9	6	3.8	T.	0.0
Boise	2,739	78	86	27.26	30.14	+.08	53.8	+2.7	80	4	68	26	30	40	39	43	31	46	0.13	−1.1	2	2,550	se.	25	ne.	7	20	6	5	3.1	T.	0.0
Lewiston	757	40	48	29.32	30.13	+.06	53.9	+2.4	87	4	68	27	31	39	42	----	----	----	0.63	−0.6	6	1,153	w.	25	nw.	17	14	14	3	3.9	0.0	0.0
Pocatello	4,477	60	68	25.57	30.10	+.06	51.0	+2.6	78	1	65	22	30	37	38	39	28	49	0.67	−0.5	4	4,432	se.	36	sw.	27	16	13	2	2.8	0.5	0.0
Spokane	1,929	101	110	28.07	30.13	+.07	51.7	+3.4	80	15	65	24	31	39	42	44	35	57	0.49	−0.7	5	2,958	ne.	17	s.	17	15	11	5	4.2	0.0	0.0
Walla Walla	991	57	65	29.04	30.11	+.04	56.3	+2.8	84	15	68	33	29	45	32	47	37	50	1.12	−0.4	5	2,329	s.	15	w.	27	17	13	1	3.3	0.0	0.0
North Pacific coast Region							**55.7**	**+3.6**										**74**	**1.72**	**−1.8**										**5.4**		
North Head	211	11	56	29.88	30.10	+.05	55.2	+2.3	80	23	60	45	29	51	18	52	50	86	1.38	−3.6	17	8,233	s.	44	s.	18	9	7	15	6.2	0.0	0.0
Port Angeles	29	8	53	----	30.10	----	50.7	----	68	1	58	37	28	44	26	----	----	----	0.93	−1.4	9	------	sw.	24	nw.	5	5	12	14	----	0.0	0.0
Seattle	125	215	250	29.96	30.09	+.04	55.6	+4.2	75	15	62	38	29	49	25	51	47	76	1.00	−1.8	9	4,575	s.	31	w.	16	8	12	11	6.1	0.0	0.0
Tacoma	194	172	201	29.90	30.11	+.07	56.0	+5.5	72	16	64	38	29	48	26	----	----	----	0.82	−2.5	10	4,122	n.	28	s.	18	1	20	10	6.5	0.0	0.0
Tatoosh Island	86	9	53	29.97	30.07	+.06	52.6	+2.7	64	7	56	44	28	49	15	51	50	95	7.04	−1.1	19	11,034	e.	43	e.	20	7	7	17	6.8	0.0	0.0
Yakima	1,076	58	67	28.96	30.12	------	54.4	------	81	15	68	31	30	40	38	45	35	54	0.05	−0.6	1	2,712	nw.	18	nw.	27	17	9	5	3.8	0.0	0.0
Medford	1,425	4	80	28.56	30.07	------	54.8	------	82	23	72	25	29	38	47	46	41	69	1.14	------	6	------	se.	19	n.	28	20	4	7	3.1	0.0	0.0
Portland, Oreg	153	68	106	29.94	30.10	+.04	58.5	+4.3	80	15	68	38	29	49	31	52	47	69	1.33	−1.8	9	2,932	nw.	20	e.	22	7	13	11	5.9	0.0	0.0
Roseburg	510	75	99	29.54	30.09	+.01	56.3	+2.4	81	15	70	29	29	43	40	50	45	72	1.21	−1.4	8	1,705	nw.	16	n.	28	11	11	9	4.8	0.0	0.0
Middle Pacific Coast Region							**62.5**	**+2.2**										**62**	**0.09**	**−1.2**										**2.9**		
Eureka	62	73	89	30.02	30.09	+.03	53.8	+0.2	73	22	60	39	29	47	23	52	50	88	0.21	−2.1	6	3,161	n.	30	n.	28	10	8	13	5.5	0.0	0.0
Red Bluff	330	5	58	29.62	29.98	−.05	67.6	+3.3	95	15	83	44	30	52	42	52	37	38	0.10	−1.2	1	3,569	nw.	26	n.	28	20	6	5	2.5	0.0	0.0
Sacramento	69	106	117	29.89	29.96	−.03	65.4	+2.5	94	5	80	40	31	51	43	54	44	52	0.15	−0.8	2	4,369	nw.	33	nw.	28	29	2	0	0.8	0.0	0.0
San Francisco	155	208	243	29.82	29.99	−.02	63.5	+3.0	90	22	72	50	26	55	31	55	50	70	0.01	−1.1	1	4,382	w.	38	n.	29	17	11	3	3.4	0.0	0.0
San Jose	141	12	110	29.84	29.99	------	62.3	+2.0	90	22	76	39	30	48	39	----	----	----	T.	−0.7	0	3,311	nw.	22	nw.	29	21	9	1	2.2	0.0	0.0
South Pacific Coast Region							**68.4**	**+4.0**										**58**	**T.**	**−0.6**										**2.4**		
Fresno	327	89	98	29.61	29.96	.00	68.2	+4.2	95	5	83	43	31	54	35	54	41	41	T.	−0.6	0	3,546	nw.	19	nw.	16	30	1	0	0.5	0.0	0.0
Los Angeles	338	159	191	29.58	29.94	−.01	70.2	+4.9	100	21	80	53	31	60	37	58	50	60	T.	−0.7	0	3,035	sw.	14	sw.	2	19	10	2	2.9	0.0	0.0
San Diego	87	62	70	29.83	29.92	−.03	66.7	+3.0	88	21	74	49	30	60	29	59	55	72	0.00	−0.5	0	3,605	nw.	19	nw.	4	14	12	5	3.8	0.0	0.0
West Indies																																
San Juan, P. R	82	9	54	29.83	29.91	------	79.9	+0.1	91	15	85	71	29	75	15	----	----	----	2.11	−4.0	15	6,341	e.	29	e.	4	9	19	3	4.7	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97	[1]29.72	[1]29.81	−.01	78.8	−0.4	89	12	84	70	30	73	16	----	----	[2]89	7.89	−2.3	18	3,769	s.	24	s.	18	0	10	21	8.0	0.0	0.0
Cristobal	38	7	97	[1]29.78	[1]29.81	−.02	81.5	+1.7	94	2	88	72	29	75	20	76	75	[2]85	13.74	−1.8	24	4,212	se.	27	nw.	20	0	12	19	7.8	0.0	0.0
Alaska																																
Juneau	80	11	50	[1]29.66	[1]29.75	------	45.8	------	54	21	50	32	20	42	18	44	42	85	17.31	------	28	7,149	e.	34	e.	12	1	0	30	9.5	0.0	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[1]29.95	[1]29.99	------	78.2	------	85	23	83	67	5	73	15	71	68	72	2.99	+1.4	17	5,210	e.	22	e.	5	14	14	3	3.9	0.0	0.0

[1] Pressure not reduced to mean of 24 hours.

[2] Observations taken bihourly.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, October, 1929*

Stations	Altitude above mean sea level Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F.	99				48.1		54.5	41.7	62	24	2.35		0.0
Sydney, C. B. I.	48	29.92	29.97	+0.01	49.4	+2.9	56.7	42.2	72	30	4.31	−0.38	.05
Halifax, N. S.	88	29.90	30.01	+.01	49.5	+2.3	58.3	40.7	73	25	2.10	−3.45	T.
Yarmouth, N. S.	65	29.87	29.94	−.08	49.0	+1.4	55.1	42.9	70	26	3.51	−0.61	T.
Charlottetown, P. E. I.	38	29.84	29.88	−.08	48.5	+2.0	54.7	42.3	70	29	3.04	−1.86	0.2
Chatham, N. B.	28	29.81	29.84	−.12	44.1	+1.1	52.6	35.7	71	20	3.78	−0.08	0.1
Father Point, Que.	20												
Quebec, Que.	296	29.64	29.97	−.03	43.8	+1.4	49.8	37.8	66	26	3.46	+0.31	T.
Doucet, Que.	1,236				36.4		44.9	28.0	60	11	2.47		0.3
Montreal, Que.	187												
Ottawa, Ont.	236	29.74	30.01	.00	46.1	+2.3	55.2	37.1	75	26	2.09	−0.46	T.
Kingston, Ont.	285	29.71	30.02	−.01	47.5	+0.5	53.6	41.4	68	24	3.22	+0.49	0.0
Toronto, Ont.	379	29.62	30.03	−.01	48.5	+1.9	55.8	41.1	72	28	2.29	−0.07	0.0
Cochrane, Ont.	930				38.0		44.8	31.2	68	17	4.53		3.1
White River, Ont.	1,244	28.69	30.02	+.04	36.6	−0.5	46.0	27.2	68	4	3.20	+0.85	3.6
London, Ont.	808				47.5		56.4	38.7	71	25	4.18		0.
Southampton, Ont.	656	29.29	30.01	−.01	46.6	+0.5	54.6	38.6	71	22	3.94	+0.77	0.0
Parry Sound, Ont.	688	29.32	30.02	+.01	44.2	+0.3	51.5	36.8	67	23	3.09	−0.83	0.8
Port Arthur, Ont.	644	29.34	30.05	+.07	44.0	+4.1	51.9	36.2	81	23	2.70	+0.14	T.
Winnipeg, Man.	760												
Minnedosa, Man.	1,690	28.24	30.08	+.11	43.7	+5.9	53.7	33.7	73	23	0.99	−0.21	8.9
Le Pas, Man.	860				42.9		52.3	33.5	72	21	0.27		0.2
Qu'Appelle, Sask.	2,115	27.78	30.04	+.07	44.8	+5.4	54.8	34.8	78	23	2.14	+1.04	18.6
Moose Jaw, Sask.	1,759				47.2		61.1	33.3	83	18	0.92		8.3
Swift Current, Sask.	2,392	27.46	30.00*	+.03	47.0	+4.9	61.1	32.8	84	19	0.36	−0.52	* 3.2
Medicine Hat, Alb.	2,144												
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Prince Albert, Sask.	1,450	28.45	30.04	+.07	44.8	+7.7	57.0	32.6	74	20	0.12	−0.71	0.1
Battleford, Sask.	1,592	28.27	30.03	+.06	44.6	+5.0	59.0	30.1	81	18	0.09	−0.36	0.2
Edmonton, Alb.	2,150												
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.84	30.10	+.09	53.2	+4.0	58.8	47.7	66	41	1.23	−1.14	0.0
Barkerville, B. C.	4,180												
Estevan Point, B. C.	20												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												

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Sydney, C. B. I.	48	30.04	30.09	+0.08	60.1	+3.6	68.1	52.2	78	42	3.44	+0.16	0.0
Halifax, N. S.	88	30.04	30.14	+.10	60.2	+2.6	69.1	51.3	78	37	5.48	+1.77	0.0
Yarmouth, N. S.	65	29.98	30.05	.00	57.2	+1.1	64.6	49.8	72	36	6.76	+3.15	0.0
Charlottetown, P. E. I.	38	29.99	30.03	+.02	59.0	+1.7	66.0	52.1	78	41	3.35	−0.05	0.0
Chatham, N. B.	28	29.86	29.89	−.11	56.0	+0.6	66.9	45.2	79	32	1.50	−1.21	0.0
Father Point, Que.	20	30.00	30.02	+.04	50.7	+0.3	58.4	43.0	72	36	1.79	−1.34	0.0
Winnipeg, Man.	760	29.16	29.99	+.05	52.1	−0.4	62.1	42.2	99	27	2.39	+0.36	0.0
Kamloops, B. C.	1,262	28.74	30.02	+.05	57.9	+0.5	70.2	45.7	86	35	0.74	−0.11	0.0
Estevan Point, B. C.	20				54.2		62.2	46.3	72	38	T.		0.0
Prince Rupert, B. C.	170				55.7		63.0	48.5	75	42	1.04		0.0
Hamilton, Ber.	151	30.00	30.16	+.09	80.0	+2.6	86.2	73.8	90	71	2.52	−3.99	0.0

Chart I. Departure (°F.) of the Mean Temperature from the Normal, October, 1929

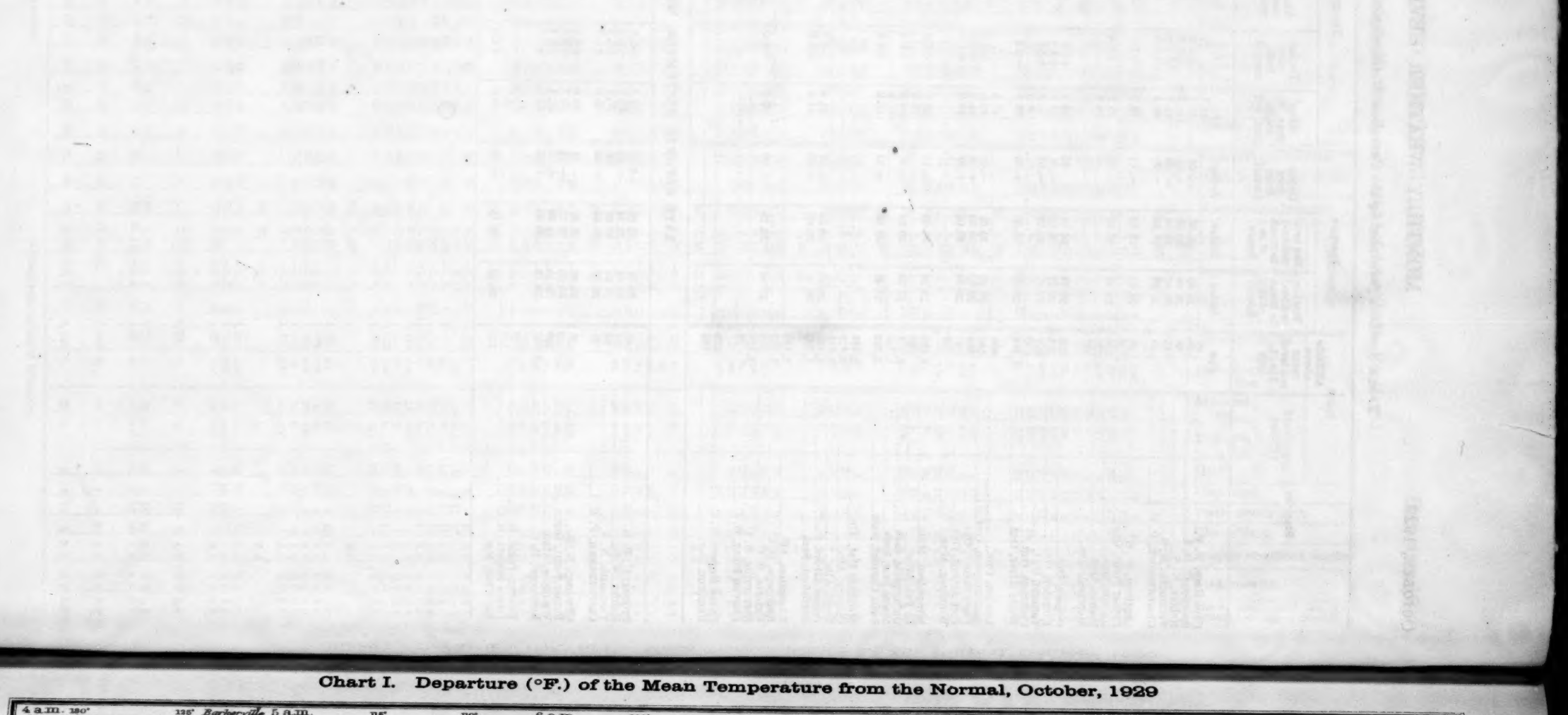

Chart I. Departure (°F.) of the Mean Temperature from the Normal, October, 1929

Chart II. Tracks of Centers of Anticyclones, October, 1929. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by Wilfred P. Day)

Chart III. Tracks of Centers of Cyclones, October, 1929. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Wilfred P. Day)

Chart III. Tracks of Centers of Cyclones, October, 1929. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Wilfred P. Day.)

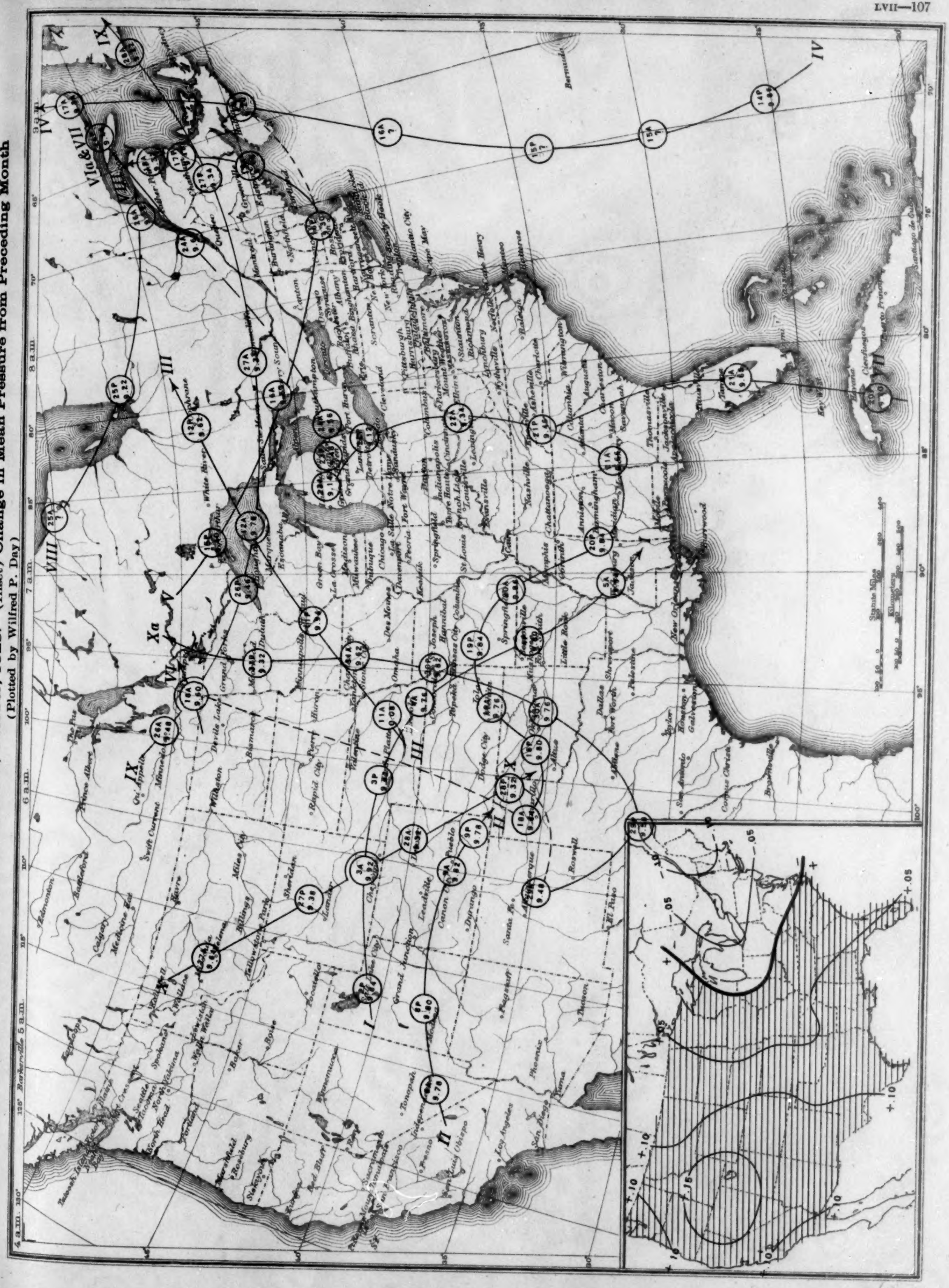

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, October, 1929

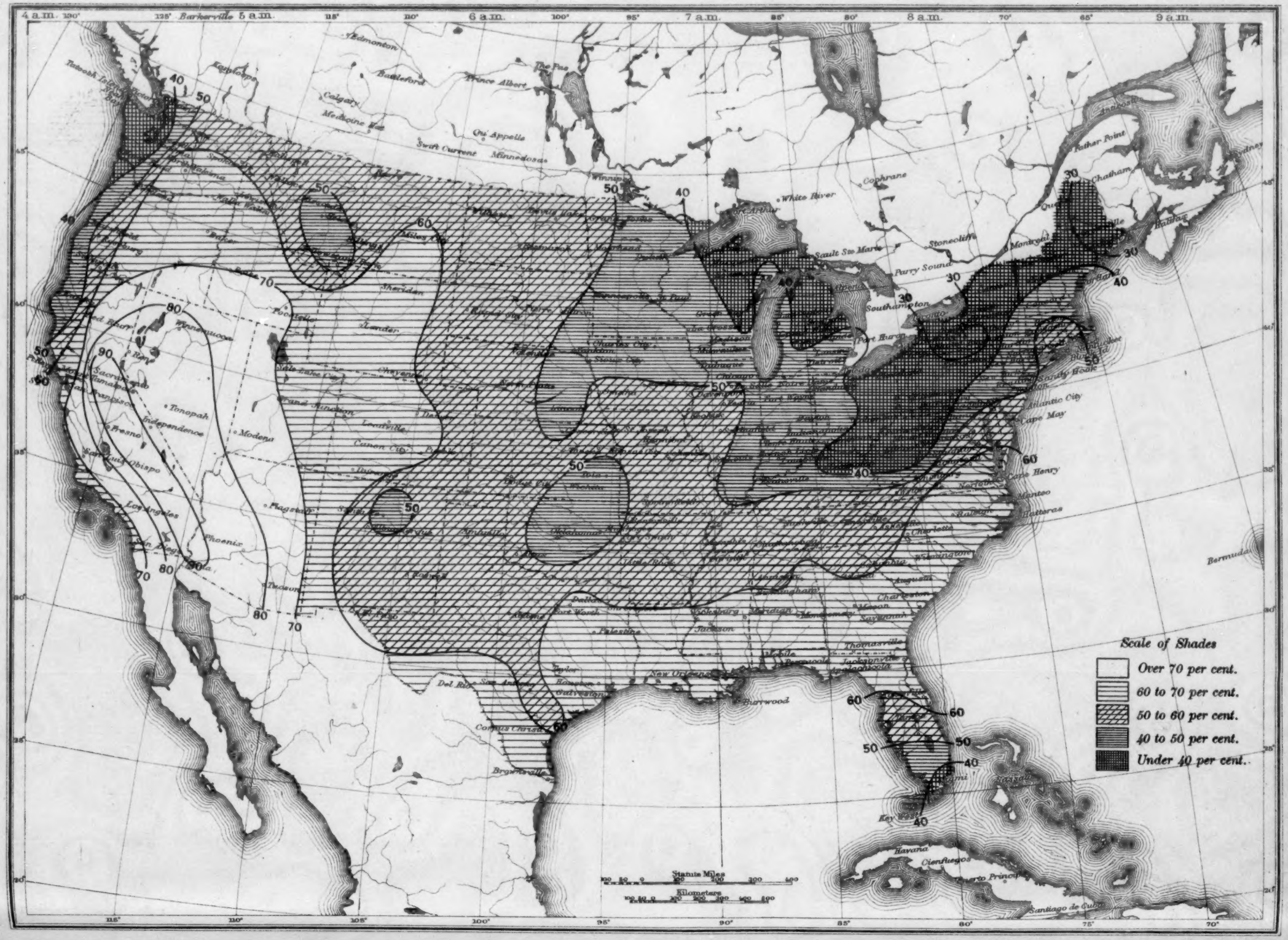

Chart V. Total Precipitation, Inches, October, 1929. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, October, 1929. (Inset) Departure of Precipitation from Normal

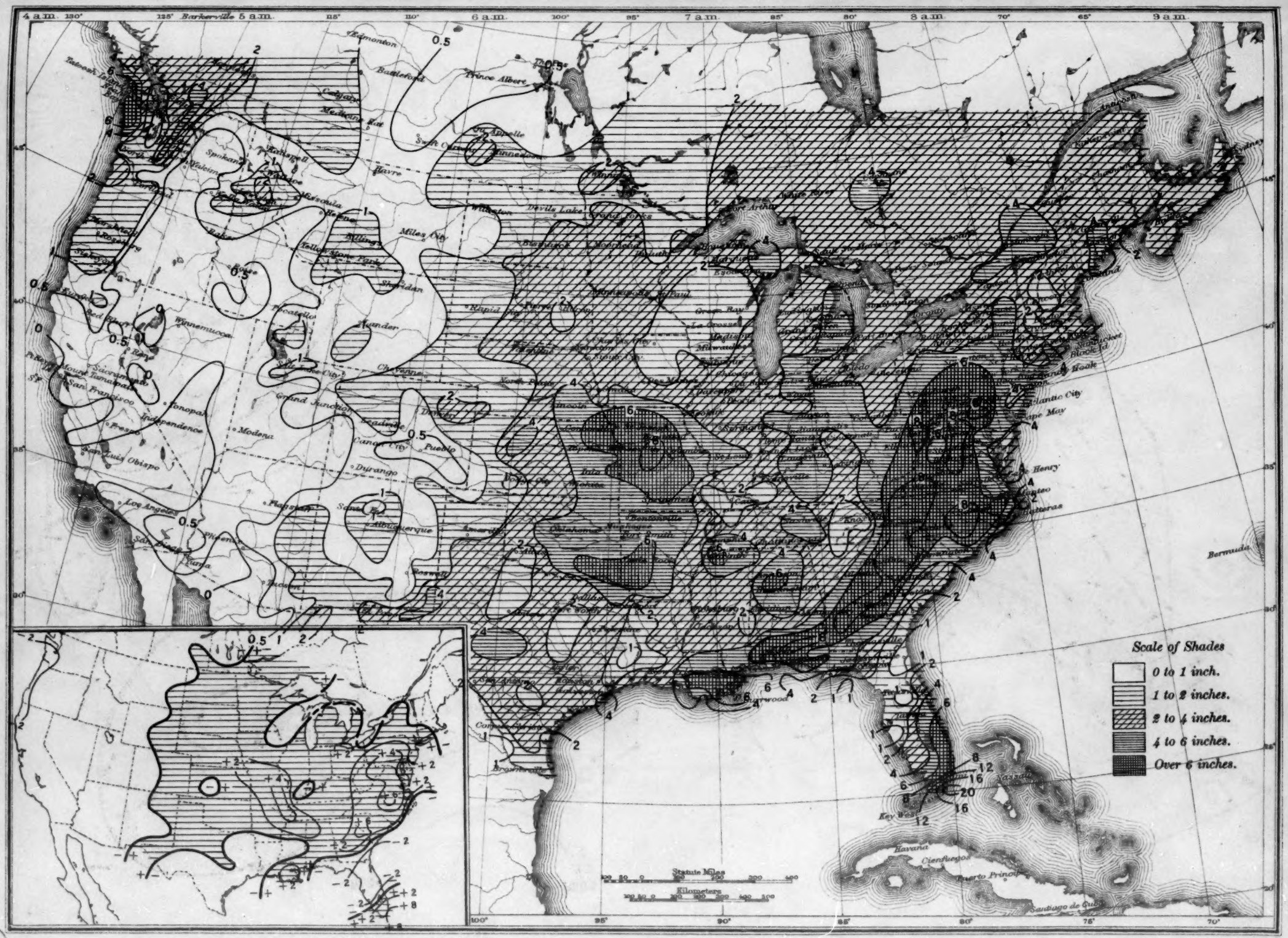

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Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, October, 1929

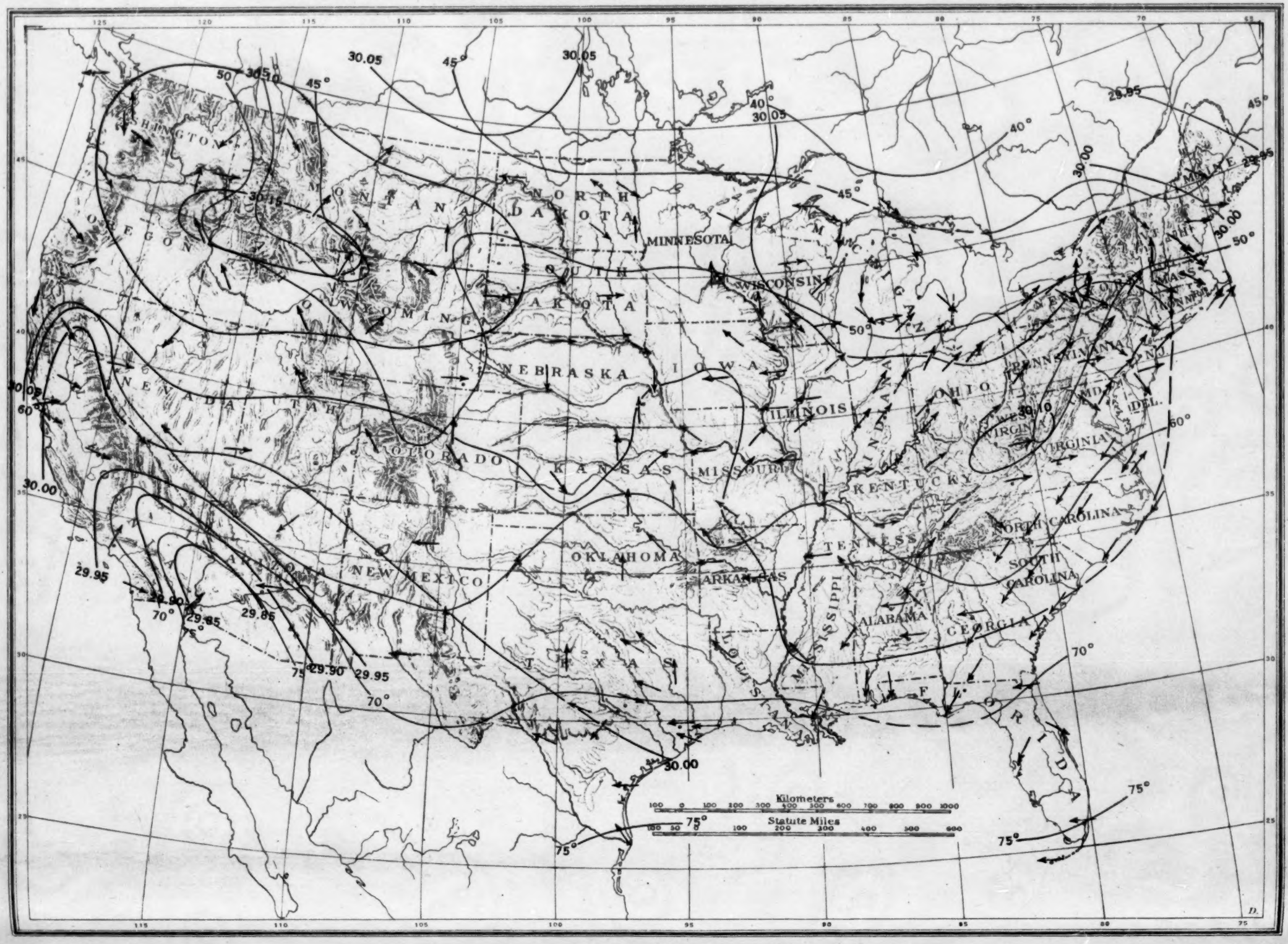

Chart VIII. Weather Map of North Atlantic Ocean, October 1, 1929
(Plotted by F. A. Young)

Chart VIII. Weather Map of North Atlantic Ocean, October 1, 1929

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

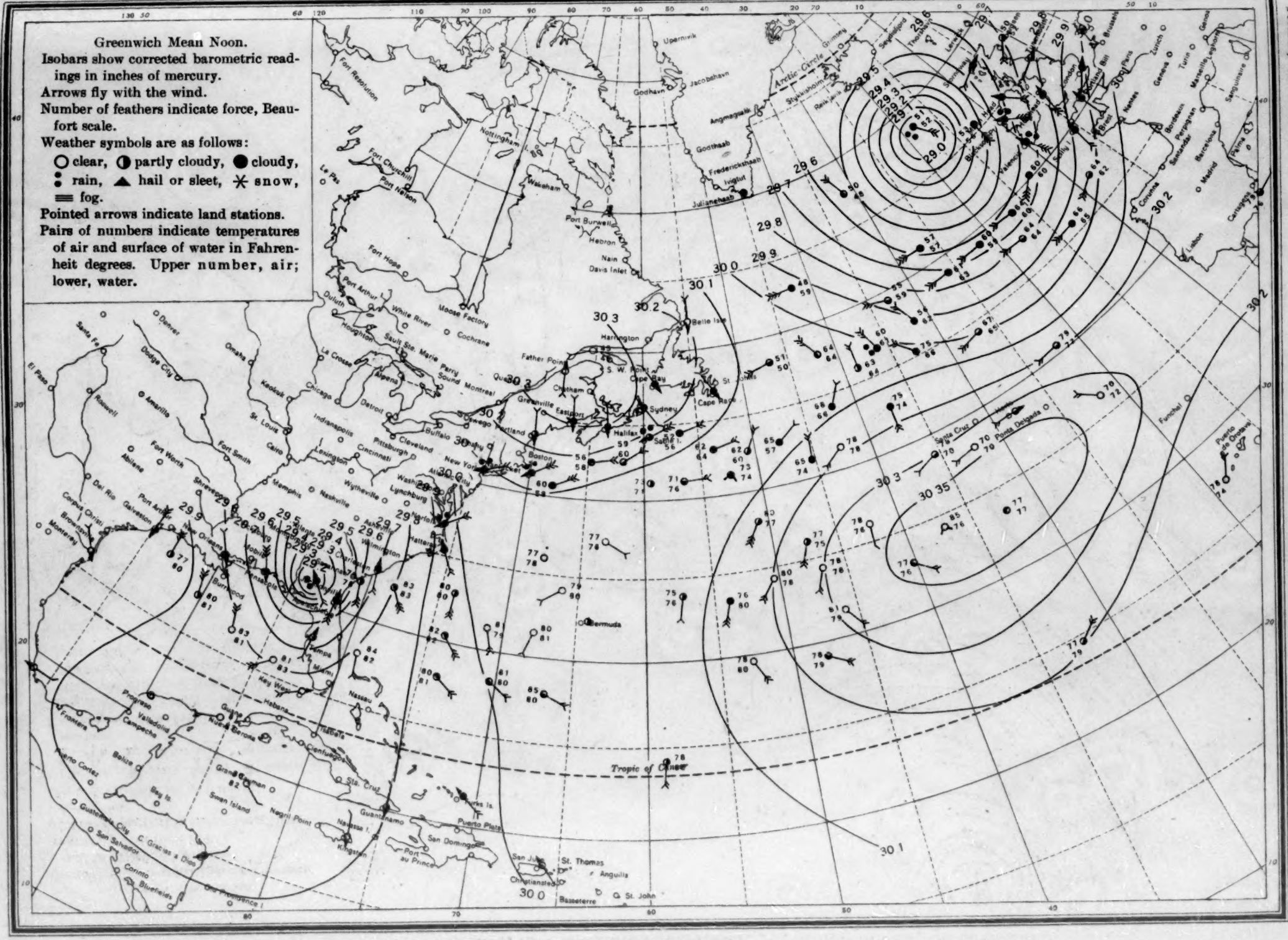

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Chart IX. Weather Map of North Atlantic Ocean, October 2, 1929
(Plotted by F. A. Young)

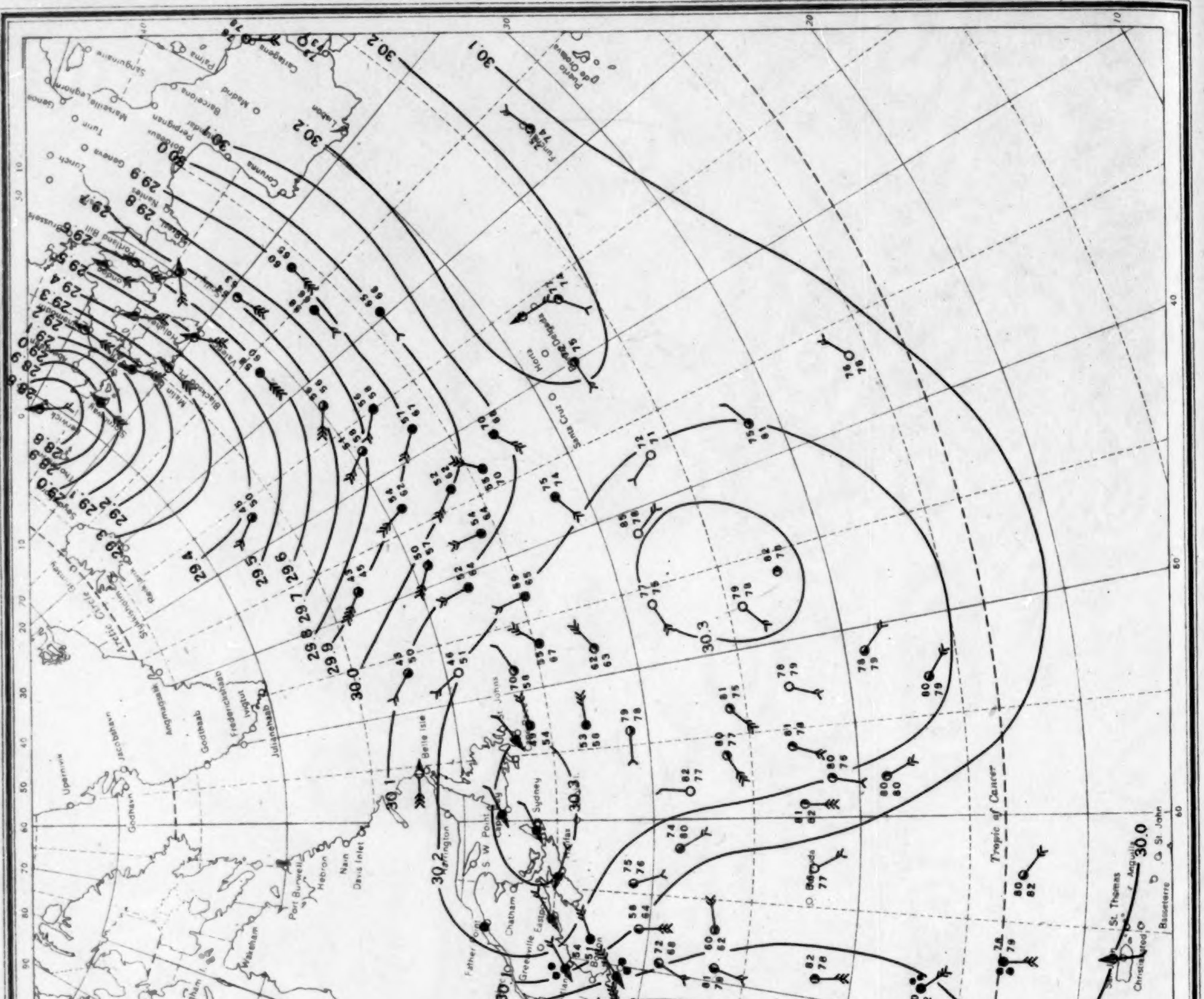


Chart X. Weather Map of North Atlantic Ocean, October 21, 1929

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

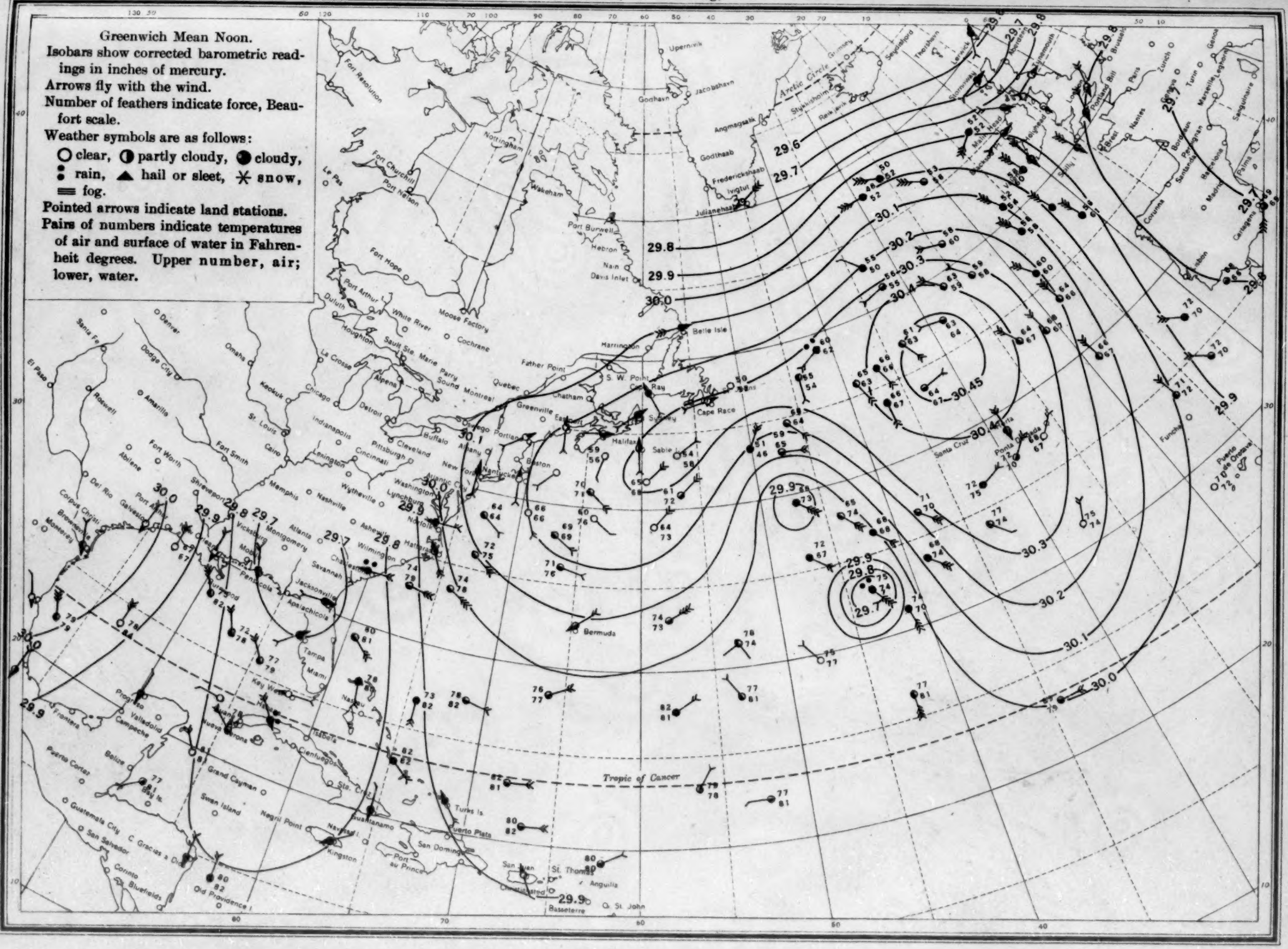
Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ═ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.



October, 1929. M. W. R.

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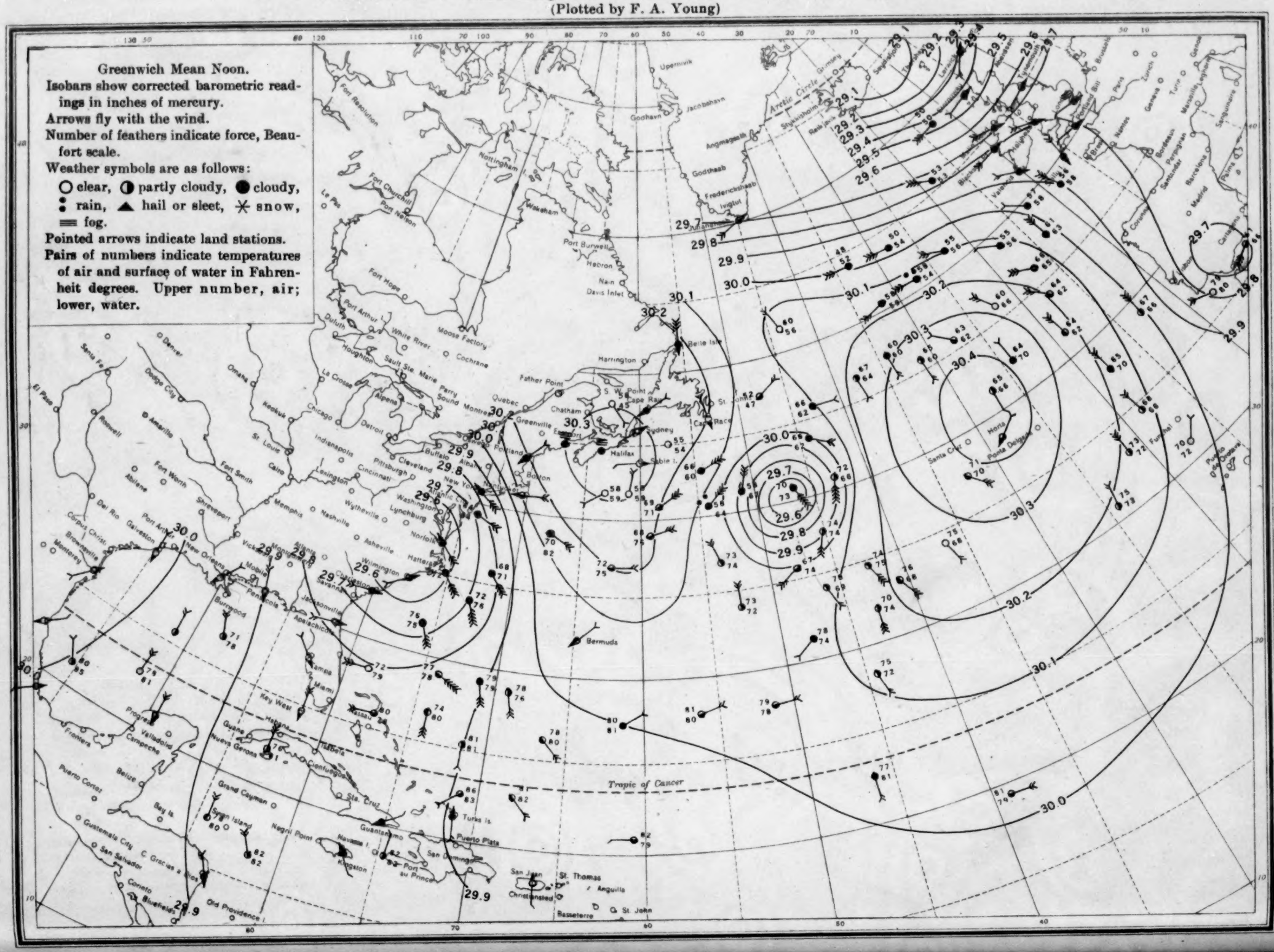
Chart XI. Weather Map of North Atlantic Ocean, October 22, 1929

(Plotted by F. A. Young)